Water and Wastewater Operators'

Basic Course

Alberta
ENVIRONMENT
Pollution Control Division
Municipal Engineering Branch

ALBERTA WATER AND WASTEWATER

OPERATORS BASIC COURSE MANUAL

MUNICIPAL ENGINEERING BRANCH

POLLUTION CONTROL DIVISION

ALBERTA ENVIRONMENT

OPERATORS' BASIC COURSE MANUAL

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INTRODUCTION

This manual has been prepared by the Municipal Engineering Branch to provide some basic information for people in the municipal water and wastewater industry. Almost all of the topics could be expanded so that each one could justify a separate manual. An attempt has been made here to combine the main areas of each topic into one manual that will be of some use to water and wastewater operators.

Advanced water treatment and wastewater treatment have been omitted from this manual and will be covered on their own by other courses presented by the Municipal Engineering Branch.

SECTION A

GENERAL TOPICS

1. GENERAL PLANT MAINTENANCE

General maintenance is ninety percent good housekeeping which consists of small tedious tasks such as wiping up oil, keeping the building clean, painting, grass cutting, etc. An operator should try to keep the plant in a neat and tidy condition and to beautify it and its surroundings.

PLANT CLEANING

Every operator of a plant and pumping station should see that a good housekeeping program is carried out at all times. Floors should be swept daily and washed every week. If tile is used as floor covering, it should be waxed and polished after every wash. Windows should be washed and all equipment should be dusted every week. Concrete floors, if at all possible, should be painted. All equipment should be dusted and cleaned and no excess chemicals should be allowed to accumulate on the moving parts. (This will add greatly to the life of the equipment.)

BUILDING

Buildings should always be kept pleasing in appearance. Discarded equipment, lumber, etc. should not be left along the sides of the buildings. This gives a plant the appearance of a disposal area. The exterior, as well as the interior, of all plants and pumping stations should be painted regularly to prevent deterioration of the structure as well as to provide a pleasing appearance to the taxpayer and the operating staff. There is nothing worse to look at than a paint peeled building. Exterior colors should be uniform throughout the system and inside colors of the plant should be bright and cheerful and in harmony. All piping should be painted periodically to prevent corrosion and also to improve their appearance. When painting the piping system, it is advisable to "Color Code" the pipes as this will permit immediate identification of a pipe's duty in relation to the system. Refer to the Color Code charts at the end of this section for correct coloring.

Windows should be kept clean and eavestroughs should be kept in good repair for appearance and to prevent roof water from spoiling the landscape. Roofs should be inspected at least once a year.

Inside, the building should be neat and tidy. Broken or burnt light bulbs should be replaced immediately and tools should be kept in their proper places when they are not in use.

LANDSCAPING

An effort should be made so that no accumulation of any sort takes place near the plant. Trash should be picked up and disposed of. A proper storage compound should be constructed away from the plant if at all possible and a refuse disposal container should be available.

Often, when a plant is completed, the grounds are left in an untidy condition. Grading, roads and lawns may be needed. In grading, steep grades should be avoided where possible. It is sometimes better to cover a steep slope with vines instead of grass. At established plants, the lawn should be kept well trimmed at all times. The planting of deciduous or evergreen trees in appropriate locations helps to blend the treatment plant into its surroundings. It is never too late to take the initial steps to make the plant area look like a park, of which the whole community can be justly proud.

COLOR CODE

Piping should be painted according to the following chart. The entire length of the pipe should be painted in the basic color and bands, if required, should be painted at thirty foot intervals or when the pipe enters or leaves a room. Individual bands are to be one inch wide and a one inch space should be left between bands when multiple bands are required.

Raw or Unfinished Water - Dark Green

Clarified Water - Dark Green with one Black Band

Filtered Water - Dark Green with two Black bands

Filtered and Chlorinated (Potable) Water - Blue

Backwash Water - Light Green

Chemical Feed Lines

- Coagulant - Pink with one Black band
- pH Control - Pink with two Black bands
- Taste and Odor - Pink with three Black bands
- Fluoride - Pink with one Green band
- Chlorine and Water - Pink with one Yellow band
- Chlorine Gas - Yellow

Plumbing (Waste) - Brown

Electrical - Purple

Compressed Air - White

Heating - Silver

Fire Protection- Red

Raw Sewage - Brown

Primary Settled Sewage Effluent - Brown with one White band

Secondary Settled Sewage Effluent - Gray

Sludge Lines

Raw Sewage - Black

Primary Sludge - Black with two White bands

Digested Sludge - Black with three White bands

Digester Liquor - Black with one Brown band

Natural Gas - Orange

Digester Gas - Orange with one Black band

Chlorine Gas - Yellow

Chlorine and Water - Pink with one Yellow band

Chlorinated Effluent - Grey with one Yellow band

Electrical - Purple

Compressed Air - White

Heating - Silver

Fire Protection - Red

Potable Water - Blue

Untreated Water - Dark Green

2. SAFETY

The dangers associated with water and sewage works operation emphasize the need for safety practices. Physical injuries and body infections are a continuous threat and occur with regularity. Explosions and asphyxiations from gases or oxygen deficiency occur at treatment plants and during sewer maintenance, and although infrequent at any particular location, on a country-wide basis many such accidents occur. Damaged clothing, burns to the skin and poisoning occur as a result of neglecting rules regarding chemicals. These occupational hazards may be largely avoided by the execution of safe practices and the use of safety equipment. The dangers are many and carelessness all to frequently prevails until an accident results. Then, it is too late.

Accident prevention is the result of thoughtfulness and the application of a few basic principles and knowledge involved. It has been said that the "A, B, C" of accident prevention is "always be careful". However, one must learn how to be careful and what to avoid. With this knowlege one can then always think and practice safety.

BODY INFECTIONS

This hazard to plant personnel although very real and ever present can be largely reduced by the operator following a few basic rules of personal hygiene. A few of these self applied rules are as follows:

1. Never eat your lunch or put anything into your mouth without first washing your hands.

2. Refrain from smoking while working in open tanks, on pumps, or cleaning out grit channels etc. Remember you inhale or ingest the filth that collects on the cigarette from dirty hands. Save your smoking time for lunch hours or at home.

3. A good policy is "never put your hands above your collar when working on plant equipment".

4. Always wear your rubber boots when working in tanks, washing down etc., don't wear your street shoes.

5. Don't wear your rubber boots or coveralls in your car or at home.

6. Always wear rubber or plastic gloves when cleaning out pumps, handling hoses etc.

7. Don't just wash your hands before going home, wash your face too, there is as much of your face to carry germs as there is of your hands.

8. Wear a hat when working around sludge tanks, cleaning out grit and other channels, don't go home with your head resembling a mop that just wiped up the floor around a cleaned out pump.

9. Keep your finger nails cut short and clean. They are excellent carrying places for dirt and germs.

Workers who come into contact with sewage are exposed to all the hazards of water-borne diseases, including Typhoid Fever, Amoebic Dysentry, Infectious Jaundice and other intestinal infections. Tetanus and skin infections must also be guarded against.

A majority of infections reach the body by way of the mouth, nose, eyes and ears. Therefore, washing your hands is a must before eating or smoking. Wear protection gloves where possible.

Soap preparations requiring no water rinse are available for field use. The common drinking cup should be banned, each man should have and use his own.

Typhoid and Tetanus innoculations are recommended. These may be obtained free of charge from local Health Unit Offices.

WEARING APPAREL

Rubber or rubberized cotton gloves, rubber boots and coveralls are designed for protecting the body against dampness and contact with dirt. Wear them at all times when working in tanks etc.

Rubberized or rain suits can be worn in very wet or dirty places and can be washed off with a hose and brush.

Hard hats should be available and worn when working below ground level, i.e. in open tanks etc., or in confined areas with low head room or during any construction on the plant site. Always wear safety goggles when grinding, chipping or scrapping or wire brushing.

FIRST AID FOR PHYSICAL INJURIES

Except for minor injuries, wounds should be treated by a doctor and reported for possible Worker's Compensation. Service truck and plants should have first aid kits and as many of the plant personnel as possible should have "St. Johns Ambulance" first aid instruction. Remember no cut or scratch is too minor to receive attention.

SAFETY IN AND AROUND THE PLANT

When working at the plant, observe the following common sense rules:

1. Walkways must be kept clear of loose objects such as pails, shovels, loose rope, etc.

2. Grease and oil should be wiped up immediately, icy walks can be salted or sanded.

3. All tools must be picked up, cleaned and returned to their storage area.

4. When it is necessary to use tools in an empty tank or manhole etc., they should be lowered in a pail on a rope and removed the same way. Brooms and shovels can also be transported by rope. Do not attempt to climb up and down ladders with your hands full of tools.

5. Don't overload yourself when using stairways, keep your load small enough to be able to see over it and have one hand free to use the hand rail.

6. Do not attempt to climb up or down a ladder or over a railing while handling a hose under pressure.

7. When washing down the floor of any tank, be sure you wear hip wader rubber boots with good treaded soles, do not wear rubber boots with worn soles and heels.

8. When working in a narrow or confined passage where grit or sludge accumulates, wear the appropriate rubber clothing provided.

9. Always wear rubber or plastic-coated waterproof gloves when cleaning pumps, handling hoses, removing grit or sludge or loading sludge trucks, etc.

10. When it is necessary to use an extension ladder to enter any empty tank, use the collector arms in clarifiers for a back-stop for the ladder legs. In an aeration tank, the ladder must be lashed. Entry with a ladder into the tank must be from a walkway (not from a narrow dividing wall) and in all cases the ladder should be lashed to a handrail.

11. Whenever working below ground level (in tanks, manholes, etc.) or under scaffolding, hard hats should be worn.

12. Do not hang clothes on electrical disconnect handles, light switches or control panel knobs.

13. Manhole covers and trap doors to wells must be replaced, and closed after use or protected by guard rails if it is necessary for them to be left open.

14. The proper tool must be used when removing or replacing manhole covers. Do not attempt to move or close a manhole cover with your hands.

15. When working in manholes located in a street or road, signs with blinking amber lights and red flags must be posted at each approach to the area.

16. When removing grit from tanks or wet wells, do not pull up pails filled with grit using a rope. Use an "A" frame and pulley or some other type of support with a pulley. The support and pulley must be fastened firmly to prevent if from toppling over during its use.

17. When leaning out through the railings over any tank (or cleaning out spray nozzles, etc.) a safety belt with a short rope and a safety snap should be used.

18. Never go out on the ice of sewage lagoons and water reservoirs as the warm ever moving sewage or the decreasing or increasing liquid levels result in unsafe ice and snow cover. If it is necessary to go on the ice, be sure to have some kind of rescue equipment and help available.

PUMPING STATIONS

Dry well: Vent fan should be started before entering the pumping station and left operating continuously while the operator is in the station.

"DANGER PUMPS ON AUTOMATIC CONTROLLER" signs should be posted at the control panel floor level, and the pump floor level.

"NO SMOKING" signs should be posted at the pump floor level.

Lock out switches at control panel should be engaged when work is being done on any pump at any floor level.

Wet Well: Vent fan should be started before entering and kept in constant operation while operator is in the area.

Use only waterproof and explosion proof extension cord lights.

Do not enter a wet well if there are strong odors present. If it is not possible to exhaust the gases with the vent fan, check the well with an explosion meter. If a .2 (or 20%) reading is recorded then self-contained air packs must be worn.

Safety harness and rope must be worn by operators when cleaning the wet well or servicing pump controls.

If a comminuting device located in the wet well requires servicing, the electrical disconnect shall be locked out and the key carried in the operator's pocket.

When maintenance work or cleanout is required in the wet well of a pumping station, the operators must enlist the aid of another man to stand by for emergencies while he is in the wet well.

THE DO NOTS OF SAFETY

Do not grease or oil or attempt to service any machinery while it is in operation. Pumps on automatic control must be locked out and the key must be carried by the operator during servicing.

Do not make any adjustments to operating machinery while alone. If it is necessary to run the unit to adjust it, a second man must be present and be beside the stop and go switch.

Do not work around electrical panels, disconnects or switches alone.

Do not enter any crawl space under flooring for any purpose until the area has been ventilated. In any case, a second man should be present.

Do not service pumps and shafts in the dry wells of pumping stations, and in plants where the pumps and shafts are less than three feet apart, without shutting off all pumps and locking them out.

Do not under any circumstances, attempt to grease or service pump shafting while standing on beams, piping, loose planks, guard rails, or by leaning over or through guard rails. If a ladder must be used, a second man must be present to hold the ladder steady and to provide any other assistance required of him.

LABORATORY

The following laboratory safety points should be adhered to:

1. Laboratory glassware must not be used for food.

2. Practise good housekeeping. Keep all unnecessary equipment out of working areas.

3. Areas around sinks and taps should be kept clear. You never know when you will have to wash chemicals off your hands quickly.

4. Wipe up all spills immediately.

5. All reagent bottles must be clearly labelled so they can be identified. The date when the reagent was made up, or received, should be on the label since some chemicals, particularly nitrogen compounds, become unstable with age.

6. When diluting concentrated acids or bases, always add them slowly to the water allowing time to cool. Use only heat resistant (Pyrex) glassware. When diluting sulphuric acid or when making up a solution of sodium hydroxide, cool the solution in a water bath.

7. Use water as lubricant when making glass to hose connections. For vinyl tubing, hot water can be used to make the plastic more pliable. Gloves should be worn when making hose connections to glass tubing.

8. Suction bulbs should be used on all pipettes. A valved type sold as a "PROPIPET" will save fumbling.

9. Combining chemicals found in your laboratory can produce unexpected and unpleasant reactions.

10. Chemicals should be disposed of in proper containers for storage or recycling. Keep in mind that used chemicals are potentially dangerous and proper disposal is very important.

    Practices such as disposing chemicals down the sink are strongly discouraged.

11. Bottles of hazardous liquids should be stored near floor level in ventilated cupboards.

12. A thorough knowledge of first aid for dealing with lab accidents is essential. Know the relevant sections of the antidote chart.

13. HASTE MAKES WASTE (and accident). Planning can save far more time than hurrying (and produces fewer mistakes).

CHEMICAL HANDLING

Ventilation: All areas where solvents or other compounds are used and stored must be well ventilated. The working area must be designed and constructed for the safety and convenience of the worker and for his efficient production. The ventilation should be by mechanical means with the air intake drawing air from the outside. In rooms where lime and other dry types of chemicals are used, dust accumulators should be installed in the air discharge pipe. The ventilation system must be in operation when chemicals are being handled.

Alum: Wear protective dust-proof equipment (goggles and nose mask) and proper clothing when handling and storing alum. Avoid skin and nose irritations by using plenty of water when washing and bathing.

Ammonia: Store cylinders in a cool, dry, ventilated place. Handle with care. An air pack should be available while handling. In case of

leaks, only trained personnel should make repairs. You must know your first aid if you handle and use this material.

Activated Carbon: Store in a dry, fire-proof space. Wear protective, dust-proof equipment (goggles and nose mask) when handling activated carbon. Do not smoke while working with or near stored material. Use plenty of water when washing and bathing.

Carbon Monoxide: Operate in a well ventilated area when working on engines using gas, gasoline or diesel fuel. Improperly vented gas heaters should be corrected.

Lime: Use protective, dust-proof equipment (goggles and nose mask) while handling lime and use a dust collecting system, if possible. Store in a ventilated, dry area. Use plenty of water when bathing and washing to prevent irritations. Consult a physician if irritation becomes severe.

Soda Ash: Handle soda ash the same as lime.

Solvents: Be careful when using solvents in confined areas. The area should be well ventilated. Clean solvents from skin to prevent irritations.

Fluoride Chemicals: Chemicals used in fluoridation are highly toxic and corrosive so they should be handled with care.

Chemicals in dry form should be stored in original containers in a cool dry place. It is highly important that men engaged in handling dry feed machines be well protected from dust during filling operations. Face masks to prevent dust inhalation, tight clothing to protect skin surfaces and rubber gloves should be worn by these workers.

Chemicals in solution form are pumped into storage facilities and no special problems are encountered provided the protective clothing and equipment used is satisfactory for the purpose.

Fluoride salts in solution and fluosilicic acid are very corrosive to metals. Plastic containers and piping are advisable for all concentrated solutions.

Chlorine: Chlorine handling safety is covered in detail in another section. The most common chlorine related safety points for municipal plants are:

1. Safety chains used on all cylinders to keep them in safe upright position.

2. Proper, working ventilation.

3. Proper, working gas masks.

These items should be checked daily.

NOXIOUS GASES, VAPORS AND OXYGEN DEFICIENCIES

The major cause of accidents in confined work areas are:

A. Lack of understanding of potential existing hazards.

B. Lack of proper testing for these hazards before entering confined areas.

C. Lack of facilities for eliminating the potential hazard through proper forced ventilation.

The following is a general outline of the characteristics of the gases concerned and the necessary information with regard to oxygen deficiency in the inspection, repair, and maintenance of sewers.

Oxygen Deficiency: Normal air contains about 21 percent oxygen at atmospheric pressure. Oxygen deficiency means an atmosphere having less than the 21 percent oxygen of normal air. Oxygen concentrations of less than 16 percent cause dizziness, rapid heart beat, and headache. Workmen should never enter or remain in areas where tests indicate such concentrations less supplied with air or are wearing self contained respiratory equipment. In cases of sudden entry into areas containing little or no oxygen, the workman usually has no warning symptoms, but loses consciousness immediately. Testing instruments should be used for this and other hazardous atmospheric conditions. Failing the use of testing equipment the installation or service area should be well ventilated and extreme caution exercised upon entry and during the work period. Workers should be alerted to evacuate should sensory or physical signs indicate a hazard from gases or oxygen deficiency.

Hydrogen Sulphide (H_2S): This gas is dangerously poisonous, highly flammable and corrosive to the eyes and respiratory tissues. It is a dangerous fire hazard and in the presence of air or oxygen it can easily form explosive mixtures.

Hydrogen sulphide is irritating to the eyes and respiratory tract, and becomes increasingly harmful with higher concentrations. It has a characteristic rotten egg smell but this should not be relied upon as a warning as high concentrations having a sweetish odor have a paralyzing effect on the sence of smell when inhaled and can cause death. Repeated exposures to low concentrations will tire the sense of smell and persons exposed may fail to detect its presence.

Persons exposed to H_2S should be removed to fresh air. If breathing has stopped artifical respiration should be applied immediately, the patient should be kept warm and a physician should be called.

Methane (CH_4): Methane is flammable and a dangerous fire hazard. It is not a poisonous gas. It belongs to that group of gases that require concentrations of at least 20,000 ppm to 200,000 ppm to produce any injury. If however, there is enough methane present to reduce the oxygen content of the air to a point below that which is necessary to maintain life, it can be an asphyxiant. It has no warning properties because it is color-less, odorless, and tasteless. Its chief danger is its' explosion hazard, and it may accumulate in poorly ventilated areas to produce an explosive or asphyxiating atmosphere.

Carbon Monoxide (CO): Carbon monoxide is a colorless, odorless and very poisonous gas. It is found in almost every industry, on our streets and highways and in the home. Carbon monoxide is the result of incomplete combustion of carbonaceous material. It can be found in storage tanks, bins, underground vaults, wells or sewers.

Carbon monoxide is an asphyxiant due to its action of combining with the haemoglobin of the blood to form a stable compound which does not then react with the oxygen which the body furnishes, and therefore does not transport this oxygen to the places where it is needed. This causes asphyxiation.

It resembles cyanide poisoning in that it does not interfere with the oxygen entering the lungs, but can keep this oxygen from combining with portions of the blood, and thus from being distributed to the many parts of the body.

When death is due to carbon monoxide poisoning the body may show cherry red blotching on various areas.

Workmen required to enter areas suspected of having unknown concentrations of this gas, even for short periods, should wear air-supplied or self-contained respiratory equipment. Failing this, adequate ventilation should be carried out. During the work period frequent tests of the atmosphere should be made.

On occasion it is necessary, when making sewer inspections and repairs, to use gasoline driven equipment. The exhaust of this equipment can present a hazard if the equipment is not located so that the prevailing winds, if any, carry the fumes away from the opening of the installation. It is sometimes necessary to use gasoline driven pumps at the bottom of the manholes and lift stations and it is of the utmost importance to extend the exhaust pipes of such machines up beyond the top of the installation. Before workers enter an area with such machines, the atmosphere of the manhole or lift station, or other place, should be checked for gases and oxygen deficiency.

When a worker shows signs of CO poisoning he should be removed immediately to fresh air. Have the worker lie down and keep him warm by whatever means are available. If breathing has stopped, apply artifical respiration immediately. Get medical aid as soon as possible.

Carbon Dioxide (CO_2): Gaseous carbon dioxide is the regulator of the breathing function in the body. An increase in the percentage of CO_2 breathed results in an increased rate of breathing. High concentrations however, paralyze the respiratory centre and cause asphyxiation and death. Concentrations in some atmospheres (oxygen deficiency etc.) are sufficient to cause symptoms in man, or even unconsciousness and death. Carbon dioxide gas is a heavy vapor, therefore, it can collect in manholes, wells, tanks, garbage dumps, etc. It does not diffuse or mix readily with air. High concentrations in the aforement places can remain for considerable lengths of time.

Intoxication from CO_2 causes excitement, headache, drowsiness, weakness and dizziness. Following the first excitement, high concentrations may result in coma, or even death.

Workmen overcome by CO_2 should be removed to fresh air. If breathing has stopped apply artifical respiration immediately and get medical aid.

Nitrogen (N_2): The only danger from inhalation or absorption of nitrogen lies in diluting the oxygen of the air to a point so low that it can no longer support life. Therefore nitrogen acts as a simple asphyxiant.

Gasoline: Gasoline is found in sewer systems, both storm and sanitary, from either leaking underground storage tanks or the dumping of gasoline and other petroleum products into the system by users of the system.

It is flammable liquid and a dangerous fire hazard with the greatest danger being from the fire and explosion possibilities of gasoline fumes.

Gasoline vapors are not considered very poisonous BUT if the concentration is such that the oxygen content of the atmosphere is reduced below that needed to maintain body life, it acts as an asphyxiant.

One gallon of gasoline has the explosive capabilities of 85 pounds of high quality dynamite.

RECOMMENDED SAFE PRACTICES IN SEWERS

1. Smoking should be prohibited

2. The use of open flame lights or heaters should be prohibited.

3. Approved electric lighting equipment only to be used.

4. Tests made to establish the presence of any gas or oxygen deficiency.

5. Two or more persons should conduct any work in sewers, after any necessary tests indicate that the atmosphere is safe.

6. When the atmosphere is safe the workmen equipped with a harness type safety belt and safety rope may carry out any work providing the safety rope is attended by the other workman on the surface.

7. If gas is present or there is an oxygen deficiency ventilation must be carried out by one means or another, preferably with a portable air blower with tests made periodically to insure the safety of the workmen.

8. If ventilation is not possible all workmen in the dangerous area should wear an air supplied mask or self-contained breathing apparatus.

9. When flushing sanitary or storm sewers by the dump method, introducing large quantities of water from a tank truck, the operator of the unit and all others in the immediate vicinity should be alerted to the danger of gases escaping from manholes due to air being displaced by the large volume of water.

10. The municipal authority concerned with the function of a sewer system should warn all industries using the system of the dangers and hazards created by the indiscriminate dumping of solvents, oils and other fuels into the system.

RESCUE OF GAS VICTIMS

Should any rescue attempt be made, the rescuer must use air supply or self-contained respiratory equipment, otherwise the rescuer may also be overcome.

Any protective equipment to be used must be put on before entering the installation.

Remove the victim to fresh air as soon as possible and apply artificial respiration immediately.

In all cases of asphyxiation medical aid should be secured immediately.

3. RULES AND REGULATIONS

The following discussion concerns the regulations governing the operation of water facilities as outlined in the Clean Water Act and Municipal Plant Regulations. Water and wastewater treatment plant operators should be familiar with the following regulations:

SAMPLING OF WATER WORKS SYSTEMS

1. A minimum of 2 bacteriological samples per month are to be submitted for analysis to the Department of Health Laboratory from each public water supply in Alberta.
2. The number of water samples to be analyzed for chemical quality shall be at least:
   (a) If the water is obtained from one or more wells, one sample each year from each well connected to the waterworks system, or
   (b) If the water is obtained from a surface source, two samples of treated water each year, one of which shall be obtained during the summer months.

GENERAL REGULATIONS

1. No person shall commence construction or renovation of:
   (a) a waterworks system, or
   (b) a wastewater treatment facility, or
   (c) a sewer or sewerage project without first obtaining a permit to construct from the Standards and Approvals Division.
2. Municipalities are to give three weeks notice to the Director of Pollution Control or the Municipal Engineering Branch before they are to discharge sewage or other wastewater to any drainage course.
3. The owner of every water facility shall notify the Director of Pollution Control of the name of the operator of the water facility and any change in operators.
4. No chemical, including pesticides, shall be used for the treatment of water, a water reservoir or in or around a water facility unless the Director of Standards and Approvals has approved the use of those chemicals for the water, water reservoir or water facility.

FLUORIDATION REGULATIONS

1. The holder of a licence in respect of a municipal plant where fluoridation is in operation shall ensure that adequate control is maintained at all times to provide a fluoride ion concentration of 1.0 milligram per litre in the treated water but:

   (a) a monthly average variation from 1.0 milligram per liter of ± 0.1 milligram per litre is acceptable, and

   (b) a daily variation of ± 0.2 milligram per litre is acceptable.

2. Sampling, Returns and Reports:

   The following monthly reports shall be made to the Director of Pollution Control and to the appropriate local health authority by the fifteenth (15th) day of the month following the date the sampling or test is made:

   (a) the daily reading of the water meter which controls the fluoridation equipment or that which determines the amount of water to which the fluoride is added,

   (b) the daily volume of water fluoridated,

   (c) the daily weight of fluoride compound in the feeder,

   (d) the daily weight of fluoride compound in stock,

   (e) the daily weight of the fluoride compound fed in the water,

   (f) the fluoride content of the raw and fluoridated water determined by laboratory analysis

      (i) treated water shall be analyzed daily

      (ii) raw water shall be analyzed at least once a week.

3. A sample of raw water and a sample of treated water are to be forwarded to the Department laboratory for fluoride analysis by the fifteenth day of the month following the date upon which the sample is taken.

4. On new installations, weekly samples of raw and treated water for a period of not less than four consecutive weeks, or as required by the Director of Standards and Approvals must be submitted to the Department of the Environment, Pollution Control laboratory to determine the fluoride concentration.

5. In addition to the reports required, the Director of Standards and Approvals or the Director of Pollution Control may require such other information as he may deem necessary.

6. The fluoridation program may be discontinued when necessary to repair or replace equipment but must be replaced in operation immediately after the repair or replacement is complete.

7. All necessary repairs to equipment must be undertaken immediately.

4. RECORDS

Importance of Records

Keeping of adequate records of performance is an integral part of good water and sewage treatment plant operation. Only by making a clear and concise memorandum of what has happened and what has been accomplished will the experiences be of assistance in meeting future operation situations. Pertinent and complete records should be used as a basis for plant operation and for interpreting the results of water and sewage treatment.

Records also provide an excellent check on things done or to be done, especially regarding maintenance problems. Equipment in treatment plants requires periodic service; some daily, some weekly, and others monthly or yearly. Adequate records show when service was last performed and when the time for service approaches. Thus a schedule can be maintained, with nothing overlooked or forgotten.

Significant details of day-to-day experience provide a running account of plant operation and thus have an important historical value. When accurately kept, records provide an essential basis for the design of future changes or expansions of the treatment plant and also can be used to aid in the design of treatment facilities for other locations where similar problems may be encountered. In the event of legal questions in connection with water and sewage treatment or plant operations, accurate and complete records would be urgently required as evidence of what actually occurred at any given time or over any particular period of time. Thus, records and their proper maintenance are essential in any type of treatment. However, only those records should be kept which are known to be useful; the temptation to accumulate data of no significant value must be guarded against.

In summary, the main functions of records are:

To satisfy legal requirements.

To aid the operator in solving treatment problems.

To provide an alert for changing raw water quality.

To show that the final product is acceptable to the consumer.

To show that the final product meets plant performance standards.

To aid in answering complaints.

To anticipate routine maintenance.

To show that the final product complies with Government requirements.

To provide cost analysis data.

To provide future engineering design data.

To determine equipment, plant, and unit process performance.

To provide the basis for monthly or annual reports.

Information to be Included

The extent to which record keeping should be practiced depends entirely upon the potential use. The type of treatment, the volume of water treated, and the kind and importance of installations auxiliary to the treatment plant will control the amount of record keeping necessary.

Some of the basic items of information to be recorded are:

Surface Source

Air temperature
Raw Water temperature
Rainfall data
Runoff data
Height of reservoir vs. storage
Capacity
Raw water quality
Raw water quantity used

Ground Source

Raw water temperature
Raw water quality
Well logs
Static levels
Pump test data
Pump performance curves
Drawdown levels
Observation well data
Quantity pumped
Pumping intervals
Recovery rates

Treatment

Amount of water treated with chemicals
Chemical dosage; pounds hr., pounds day
Total amounts of chemical used
Amount of water filtered
Number of filters in service
Number of hours filters are in service
Final loss of head before filter was washed
Amount of washwater used
Length of time washwater was applied
Rate of wash
Cycle times for diatomaceous earth filters, pressure filters, sand filters, etc.
Daily or more frequent results of chemical, physical and bacteriological laboratory tests
Minimum, average, maximum figures for laboratory testing

Pumping Stations

Total amount of water pumped
Amount by each pump
Suction and discharge pressure

Other

Maintenance schedules
Distribution system pressures
Master and individual meter

Number of hours run by each pump
Daily power consumption
Fuel Consumption
readings
New valve and hydrant installations

<u>Sewage Lift Station</u>

Pump lubrication
Float switch operation
Flow recordings either by flow charts or by electrical consumption if there is a separate meter for the pumps
General physical remarks about sludge and pump noise

<u>Sewage Lagoon</u>

Filling and drawdown cycle of cells
Chemical treatment record
Time and period of algae growth
Sludge build-up
Excess odors, grass growth
Periodic sampling of lagoon effluent quality
Starting date and shutoff dates of lagoon drainings
Inspection of drainage course.
Complaints

In addition to these basic data items each water supply system should have;

Hydrant and valve maps for the distribution system
A list of material and equipment suppliers
A central file of instruction manuals for treatment equipment or processes; operational guides for waste control facilities
A description of the basic functions of automatic control system
Engineering plans and specifications for past construction
Names, addresses, and telephone numbers of nearby operators and personnel of the city, county, district, regional health office, and government.
The procedure for adjustments necessary in case of a major fire.

The above are just a few of the many data items that make up good records. Each water supply system has its own critical areas for which data is necessary.

When laboratory determinations are made, it is essential that not only the final results of each test be recorded, but also that all of the test data, frequently called the working data, such as buret readings and the necessary computations, be noted for future reference. Although such details may seem unnecessary, should any question arise as to the accuracy of final data obtained in the laboratory, the notes on technical procedures, if available, will be evidence of the accuracy or inaccuracy of the final result reported. Thus, to maintain the

integrity of his work, the analyst in the laboratory should keep complete records.

Frequently, state and municipal regulations govern the operation of water treatment installations. These regulations require that certain operating records be maintained and reported to the supervising agency at specified intervals. These records must be kept, but should be in addition to adequate plant operating data and should not be considered a substitute for plant records.

How Records Should be Kept

Record systems can be either simple or complex. However, they should be realistic and apply to the operating problems involved at each particular treatment facility.

The most efficient way to keep records is to plan what data are essential and useful and then to prepare forms on which the information may be quickly entered in the proper spaces. Prepared forms can be used for both plant operations and laboratory determinations. To keep records without the use of well designed forms increases the labor and time involved and promotes inaccuracies. It must be remembered that inaccurate or incomplete records are worse than no records at all. Business firms specializing in the printing of forms usually have staff trained to give advice in setting up records systems and choosing the type of form best suited to the need. Forms in use at treatment plants of a similar type are useful as guidelines when preparing forms, and can be obtained on request.

Records should be permanent, and consequently entries on the forms should be made with ink or with indelible pencil. Ordinary lead pencil notations smudge easily and can be erased or altered; a lead pencil should never be used.

Once made, records of any type should be carefully preserved and filed where they can be located rapidly. This requires the establishment of a filing system that will be used and understood by everyone concerned with making and using records. Therefore, the filing of completed record forms must be attended to promptly. A record misfiled is a record lost, and a lost record is of no value.

A pertinent question which always arises is how long records should be kept. Obviously, they should be kept as long as they may be useful, with due consideration given to the historical value of some types of data. Some information may be found of great value even after many years.

Any data that might be used in future as a basis of design for plant expansion or for new construction should be kept indefinitely. Results of laboratory analyses will always be pertinent and likewise should be kept indefinitely. Detailed operating data related to a given treatment device may have little permanent significance and can be kept

for a year, or some other indicated period, and then discarded. Official approval is required before some types of records can be discarded or destroyed. The fact that old records are not consulted every day does not lessen their potential value. It is the best modern practice to set up a disposal schedule for each type of record maintained in order to avoid the accumulation of useless files. A decision can be made at the time a record is set up limiting the period for which it must be available.

Records must be stored in a manner to insure their permanence and safety, as well as their accessibility.

Records should be made at the time the data are obtained by the person directly concerned with making the particular measurements. Responsibility for proper filing, care, and use of records will rest with the supervisor or the person in charge of the treatment plant, or someone delegated by him.

For water and sewage treatment plants, a maintenance and operation program is essential to bring about the best results at the least cost. Systematic sampling for analyzing raw and finished water enables the operator to control chemical feed rates, flow rates, and detention time and is part of the procedure.

Chemical and bacteriological analysis should be made at regular intervals in order to ensure that the product meets acceptable standards.

The Department of Environment requires that these records be kept. These may include fluoride and chlorine feeds and residuals.

Following are just a few examples of the record sheets that one could use. These headings could be used as is or added to or changed in any way to suit the operational needs and requirements of any particular operation.

WATER CONSUMPTION AND TREATMENT

Municipal Supply For ______________________________

Month of ______________________ 19 __

Meter Units ______________________________
(cu. ft., Imp. Gal., etc.)

DAY	VOLUME OF WATER		TREATMENT		
	Meter Reading	Daily Meter Through Put	Chlorine Free	Chlorine Total	Other Chemicals Than Fluoride
1					
2					
3					

HYDRANT INSPECTION REPORT

Hydrant No. ______________________ Date Installed ______________

Location ______________________________

Make ______________________ Size of Barrel ______________

Paint: Color ____________ Condition ____________ When Painted ________

No. of Outlets __________ Hose ____________ Pumper Outlet ________

Pressure ______________________________

Does aquaphone indicate leakage? ______________________

If so, date of repair? ______________________

Was hydrant flushed? ______________________

Water muddy? ______________________

Did it finally clear? ______________________

Did hydrant flush freely? ______________________

Was pressure applied? ______________ Date Corrected __________

Stem Oiled? ______________ Caps Lubricated? ______________

Further Repairs Needed? ______________ Date Completed __________

Date last inspected? ______________ By ______________

Remarks ______________________________

____

WATER USAGE — CHLORINATION

DAY	METER READING	DAILY PUMPING	WEIGHT OF CYLINDER ON SCALE	WEIGHT OF CHLORINE IN TANK	CHLORINE RESIDUAL FREE TOTAL	REMARKS
1						
2						
3						

WATER WELL RECORD

WELL No.________

DAY	HOUR	ELEVATION STATIC LEVEL	WATER ELEV.	STABILIZED PUMPING LEVEL	DRAW DOWN	PUMP SETTING	CHOKE	GPM	REMARKS
1									
2									
3									

SEWER MAINTENANCE

MANHOLE NO.	LOCATION	CHANGE IN DIRECTION	CHEMICAL IN, AMOUNT	TREATMENT FLUSHED	COMMENTS

FLUORIDE

MUNICIPAL SUPPLY FOR .... MONTH OF .... 19 .....

*METER UNITS .... **CHEMICAL COMPOUND USED ....
cu. ft. Imp. Gal., etc.

METER FACTOR .... STRENGTH OF CHEMICAL ....

DAY	*VOLUME OF WATER			**FLUORIDE CHEMICAL-lbs			FLUORIDE CONTENT p.p.m.	
	METER READING	DAILY METER THROUGH PUT	ACCUMULATIVE DAILY THROUGH PUT	IN STOCK	IN FEEDER	AM'T USED	RAW	TREATED
1								
2								
3								

Alberta ENVIRONMENT Pollution Control

SECTION B

WATERWORKS

5. CHLORINATION

Chlorine is one of the most widely used chemicals in the field of water and sewage treatment today. It's disinfecting characteristics make it a very valuable tool for water purification.

There are three major types of chlorine and each has its advantages for specific applications. The types are gas, sodium hypochlorite and calcium hypochlorite. Treatment plants serving larger communities usually use chlorine gas since it is more economical and easier to handle than the others when treating large volumes of water. Chlorine gas comes in cylinders which hold about 150 lbs. or ton containers which hold approximately 2,000 pounds. Smaller treatment plants may use sodium hypochlorite or calcium hypochlorite since they are more suitable for treating small volumes of water. All of these chemicals, when correctly used, will help to control taste, odor, color and algae problems and most important, make the water bacteriologically safe.

Because chlorine is a potentially hazardous chemical, every operator should familiarize himself with its characteristics.

PROPERTIES

Chlorine, in its pure state, is a greenish yellow gas or clear amber liquid. It has a very sharp penetrating and characteristic odor which is easily identified. Chlorine as a gas or liquid is non-flammable and will not explode. Care must be exercised though, as it can support the combustion of some organic chemicals or metals at high temperatures.

Chlorine is only slightly soluable in water, and upon dissolving it forms weak solutions of hydrochloric and hypochlorous acids. The second acid acts as the disinfecting agent. Both types of hypochlorite act in much the same manner as chlorine.

The hypochlorites are very different than the elemental chlorine which is available in cylinders. Calcium hypochlorite is usually in a granular or powder form which is normally dustless and free flowing. This type is quite easily handled and does not cause any great problems. The sodium hypochlorite is in a liquid form, very similar to household bleach. The disinfecting properties of the "hypo" types of chlorine are very similar to that of pure chlorine but the amount of available chlorine in each varies.

Sodium Hypochlorite	5 - 15% available Chlorine
Calcium Hypochlorite	approximately 65% available Chlorine
Chlorine Gas	99.8 available Chlorine

HANDLING AND OPERATION

A. Pure Chlorine Containers:

All Chlorine containers are pressure tested steel vessels equipped with safety devices to prevent handling accidents.

These devices are:

1. Valve outlet threads are special stright threads which connect only to the corresponding type of chlorine junction. Never force connections that do not fit.

2. Cylinder valves are equipped with a fusable plug which is designed to melt between 65°C (158°F) and 67°C (165°F) thus releasing pressure in the container and preventing rupture. Never tamper with the fusable plug.

3. Cylinders are equipped with a protective hood to keep the valve from being damaged. Never lift a cylinder by means of the hood.

A number of precautions must be carried out when handling containers of chlorine. When moving containers, the protective hoods should be in place and only special hand trucks or hoists should be used. These must be of the type which have a clamp or special carrier. Never drop containers or allow any object to strike them with force. All chlorine containers should be protected from external heat sources and stored in a dry area. Never store containers near turpentine, ether, ammonia, hydro-carobons, or other flammable materials. The storage area should also be well ventilated with the forced air intake at floor level, and not situated near elevators or ventilating systems as the gas may spread to other locations. The cylinder should be stored in an upright position, with the hoods on. All cylinders should be chained or clamped to a wall. Ton containers are stored on their sides above the floor. Never stack containers and always store full and empty containers separately.

Cylinders deliver chlorine gas when upright and liquid when inverted. Ton containers with the valves in a vertical line deliver gas from the upper valve and liquid from the lower valve. Normally, the gas form is used. Discharge rates may be increased by circulating room temperature air around the container with a fan. Never place the container in a both of hot water or apply direct heat.

Whenever a new container is connected, a new gasket of antimony lead, which is usually provided by the supplier, should be used. Never try to reuse gaskets. Also use only an approved wrench not over 6" long for opening the valve. One complete counter-clockwise turn of the stem permits maximum discharge. If the valve is difficult to open the packing nut may be loosened slightly, the valve opened, and the packing nut retightened. If necessary, the end of the approved wrench may be

struck with the heel of the hand to loosen a stuck valve. After connecting always test the system for leaks.

As soon as a chlorine container is empty, the valve should be closed, the lines disconnected, and the valve tested for leaks. Several successive closures of the valve may be required to obtain a good seat.

B. Calcium Hypochlorite:

Calcium Hypochlorite does not usually present a handling problem since it is in a granular or powder form. It should be stored in a cool, dry, ventilated room preferably away from any type of ammonia or flammable substance. It is flammable at temperatures over 100°C. Glass, rubber, plastic or stoneware should be used for handling and storage. If powder is used, a filtration type mask should be worn when necessary since the dust is quite toxic.

C. Sodium Hypochlorite:

This liquid form of chlorine should be handled in the same manner as Calcium Hypochlorite. It is added to the water at a predetermined rate, usually through a metering device. The metering system should be checked periodically for leaks and serviced at least yearly. Rubber, plastics, glass, or ceramics should be used for storage handling and the liquid should not be exposed to light.

SAFETY

A. Gas:

Wherever chlorine gas is used, training for both new and old employees should be conducted periodically to ensure a high degree of safety in handling procedures. A pre-requisite for safety is making a self contained breathing apparatus available to every employee involved with the chlorine. The apparatus should be located at readily accessible points away from the area likely to be affected in case of an accident, and employees authorized to act in an emergency should thoroughly understand how to wear the masks, and how to operate the apparatus. A bad gas mask is worse than no mask at all. Cannister type masks should not be used.

The gas is a powerful respiratory irritant and in sufficiently high concentration, may cause death by its smothering action. The presence of chlorine can be detected at concentrations far below the injurious level, by its characteristic appearance and smell. At these levels chlorine gas makes breathing difficult. The human reaction to chlorine is:

Least detectable odor....................................3.5 p.p.m.

Least causing throat irritation.........................15.1 p.p.m.

Least causing coughing ....30.2 p.p.m.

30 minutes exposure dangerous........................40-60 p.p.m.

Many leaks can be prevented by yearly cleaning and maintenance of the chlorinator. When a leak is detected, it can usually be stopped by immediate attention. To locate the source of a leak, a strong ammonia soaked rag or preferably an ammonia filled squirt bottle should be used. The chlorine gas reacts with ammonia to form ammonium chloride, a heavy white smoke. When using this method, always keep on the windward side of the leak. If the leak is in the chlorinator, or feed lines, the system must be shut down immediately, using the correct procedure. If the leak is in the container and cannot be effectively stopped in a short period of time, the container should be moved outside and positioned so that only chlorine gas can escape. If the leaking gas cannot be vented, introduce it into a solution of 10 lbs. of hydrated lime or 25 lbs. of caustic soda in 10 gallons of water. A drager tube apparatus can also be used for chlorine gas detection.

When chlorine is detected in the atmosphere by smell or sight take the following precautions:

1. Avoid panic.

2. Refrain from coughing.

3. Keep mouth closed as much as possible.

4. Avoid deep breathing.

5. Keep the head high (Chlorine seeks lowest level)

6. Withdraw from the affected area.

7. Notify all personnel.

First aid for chlorine exposure involves removing the subject from the area, usually while wearing a gas mask. Then, ensuring that the person is breathing by using oxygen or artificial respiration. Be certain that someone is stopping the leak and then call a physician. Liquid chlorine in contact with the eyes, skin or clothing may cause burns so all affected clothing should be removed. Properly designed emergency showers and eye baths should be placed in convenient locations wherever gas chlorine is used. If a chlorine leak cannot be handled promptly, the nearest office or plant of the supplier should be called for assistance.

If a fire occurs, chlorine containers should be removed from the fire zone immediately. If no chlorine is escaping, water should be applied to cool containers that cannot be moved. However, never use water on a chlorine leak as the resulting corrosive action will make the leak worse.

Although the procedures for handling gas chlorine seem very dangerous and complex, it is a relatively safe chemical. If all safety precautions are observed, and personnel is properly trained, serious accidents need never occur.

B. Hypochlorite:

Both types of hypochlorites are relatively simple to use, and create very few safety problems. When in solution they should be treated in the same manner as strong household bleach. Store them in a cool dry place. Wash all areas splashed by the solution and if the hypochlorite comes in contact with the skin, be sure to wash the affected area well. When mixing calcium hypochlorite the worker should wear protective equipment such as goggles or gloves and possibly a filtration mask.

PRINCIPLES OF OPERATION OF CHLORINATORS

A. Gas Chlorinators:

Gas chlorinators consist of two basic components; the vacuum regulator and the ejector. Water under pressure flows through the ejector at high velocity and causes a vacuum, which opens a spring-opposed diaphragm check valve in the ejector body.

When the spring-opposed check valve opens, a vacuum is carried to the vacuum regulator section. This vacuum causes the diaphragm to open the chlorine inlet valve, permitting gas to flow. Chlorine enters the vacuum regulator section of the chlorinator, where it is filtered to remove any foreign material that may be present. The spring-opposed diaphragm regulates the vacuum at this point.

Chlorine gas passes through the flow meter and rate control valve to the ejector, where the chlorine is thoroughly mixed with and dissolved in the water and carried as a solution to the point of desired chlorination through the ejector outlet.

B. Solution Chlorinators:

A basic set-up for solution feeding would consist of a suitable container made of material resistant to chlorine, and a metering device to add the proper amount of chlorine. The most popular type being used is the diaphragm pump. They are usually of the type which has a straight motor and gear reduction assembly, accentuating a flexible diaphragm. These incorporate suction and discharge valves and a means for varying the stroke length of the pump. A graduated scale allows the operator to read off the stroke length setting, usually in per cent.

6. INTRODUCTION TO WATER TREATMENT

Water for domestic use is treated so that the user will have a good, clear, pleasant tasting and safe water supply. Of course, it is not always possible to achieve all of these. The quality of the water depends on the raw water and on the degree of treatment. The most important thing is to have water that is safe. This means that it will not be harmful to humans.

There are two basic sources of water supplies. These are groundwater which includes wells and springs, and surface water which includes rivers, streams and lakes. Generally groundwater requires less treatment than surface water.

One important objective of water treatment is to insure that the water product is bacteriologically safe to drink. Other objectives are to remove turbidity, color, taste and odor, iron, hardness, or to control corrosion.

Water treatment can be separated into three basic areas. These are:

1. Removing Bacteria

2. Removing Unpleasant Taste and Odor

3. Removing Turbidity and Color.

REMOVING BACTERIA

Bacteria is removed from a water supply by using a strong disinfectant. Generally the disinfectant which is used in water supply is chlorine or any of its compounds such as calcium hypochlorite or sodium hypochlorite (bleach). In order to ensure that there is a bacteria kill, a free chlorine residual of 0.5 p.p.m. must be maintained after 20 minutes of contact time.

REMOVING UNPLEASANT TASTE AND ODORS

Tastes and odor problems could occur from the presence of hydrogen sulfide and other gases which are generated due to a lack of oxygen. Sources of water with deficient oxygen are cool stagnant bottoms of lakes and reservoirs during late summer and late winter and also sluggish river flows. Dead weeds or decaying vegetation are other sources which will contribute taste and odors in a water supply.

Algae is a common cause of most taste and odor problems. Algae can be removed by treating the water with copper sulphate.

Phenols are another cause of taste and odors. Normally phenols are wastes from the petro-chemical industry, however, in some instances phenols have appeared when there is heavy weed growth in reservoirs.

Taste and odors can be removed from the water by several processes. Aerating the water either by injecting air or by dropping the water through a series of trays and forcing air through trays is a common method. This process is useful in removing taste and odors which are a result of hydrogen sulfide, other gases or a stagnant supply. Aeration is not effective in removing tastes and odors which are caused by algae or phenols.

Activated carbon is a common chemical used in removing taste and odors caused by algae and phenols. Color, to a degree will also be removed by activated carbon. If activated carbon is used it must be added before chlorination, otherwise the activated carbon will remove the chlorine.

Strong oxidizing agents such as potassium permanganate and chlorine dioxide are very effective in removing tastes and odors from a water supply.

Iron in a water supply could lead to taste and odor problems. Certain types of bacteria can survive in a distribution system which utilize the iron as a source of energy. The growth and decay of these microorganisms (iron or slime bacteria) will result in taste and odor problems.

REMOVING TURBIDITY AND COLOR

The term turbidity refers to the finely-divided suspended and colloidal material which is too light to readily settle out of water. Color in water is caused by dissolved organic matter, which results from decaying bacteria and vegetation.

Turbidity and color are removed from water by using chemicals and filtration.

Chemical coagulants such as alum and lime are mixed with the water in large mixing chambers. These coagulants form a gelantinious sticky precipitate, which adsorps and entraps dirt, bacteria and suspended solids. Slight agitation of the water-coagulant mixture allows this gelatinious mass to build up into clumps of floc, which are readily removed by settling.

The treated water is detained in settling tanks for periods varying from 2 to 6 hours during which time the floc settles out. From the settling tanks the water is transferred to filters. The purpose of the filters is to remove minute impurities from the water. There are two types of filters: gravity or pressure. The gravity filter is an open tank containing a straining system (media) and underdrains for the passage of filtered water. The filter media may consist of graded sand

and gravel, with a top dressing of anthrafilt, or anthrafilt alone. The filter is equipped with back-washing facilities for periodic cleaning of the media of accumulated impurities. In operation, water flow by gravity through the filter and the impurities contained in the water are transferred to the media. The filtered water then passes through the underdrains into a clear water reservoir.

The pressure filter is a steel tank consisting of the same filter media materials as the gravity filter, except the water is forced through under pressure.

Any or all of these treatment methods can be used for a particular water supply. There is no set formula or process for producing a good finished product. There are no two water supplies that are identical so a treatment process must be adapted to the water. Also, a supply may change throughout the year. This makes constant care a necessity for a water treatment plant operator.

7. RESERVOIR OPERATION AND MAINTENANCE

Many communities in Alberta do not have a continuous supply of raw water. This makes it necessary to store water in reservoirs for the seasons of the year when raw water is not available.

Good maintenance of reservoirs is very important since everything that is in or near the reservoir may end up in the community's water.

The most obvious maintenance chore is to keep a good fence around the reservoir. This is absolutely necessary so that people and especially animals, such as dogs and livestock, cannot get near the reservoir. The fence will keep children from playing near the reservoir. This will not only protect the water supply but it will prevent the children from drowning. Fences and gates should be checked constantly to ensure that they are always in good repair.

A regular program should be set up for grass and weed cutting. The berms should be cleaned up several times a year. The weeds that grow in the water should also be removed a couple of times a year. If they are allowed to remain, they will die, rot and cause a taste and odor problem in the water. Also the cuttings on the berms should be removed, by hand if necessary, to be sure that they do not get into the water.

The use of pesticides for weed control in reservoirs is not recommended. The only chemical that should be used is copper sulphate. Copper sulphate will control algae which causes a bad taste and odor and may cause turbidity and apparent color in the water.

Reservoirs should be treated with copper sulphate at least three times a year. The first application in late spring, the second near the first of July and the third in the fall. It may be necessary for additional applications, especially in July and August. The recommended dosage of copper sulphate is 0.5 p.p.m. or 5 pounds per million gallons.

Copper sulphate must be applied uniformly over a reservoir. Dumping a large amount in one corner will not kill the algae in other parts of the reservoir. In large reservoirs the simplest manner of application is to drag burlap bags containing about 50 pounds of copper sulphate each through the water by means of a rowboat. The boat should systematically follow parallel paths of about 15 to 20 feet apart until the reservoir has been completely covered, and one-half of the required amount of chemical has been added. The boat should then operate at right angles to the previous paths to apply the remaining half of the copper sulphate.

The reservoir berms should be checked periodically for erosion and leakage. Burrowing animals can weaken berms. These animals, such as muskrats, should be controlled. The job of checking the berms is made far easier if the area surrounding the reservoir is kept well maintained. Also, all devices such as valves, should be well marked and should be checked periodically.

8. MAINTENANCE OF WATER DISTRIBUTION SYSTEMS

A municipal water distribution system does not require a great deal of maintenance to provide years of trouble-free service. Leaks will of course occur, but generally they cannot be forseen or prevented. Water main breaks or leaks must be repaired as soon as they are detected, so it is imperative that a good supply of pipe, tees, elbows, plugs, saddle clamps etc. is kept on hand. A regular program of leak detection will enable the operator to discover leaks at an early stage and repair them before too much damage is done. A sudden jump in the amount of water being treated may indicate a major leak or break, as will a drop in line pressure in the vicinity. Various electronic instruments which detect the sound of a leak are also available.

The most important aspect of operating a water distribution system is knowing the location of all of the various components of the system. This means that an up-to-date set of "as-built" plans must be kept on hand. The plans should show the exact location of all water mains, valves, and hydrants. The location of valves must be known so, in the event of a break, the line may be isolated to disrupt service to the fewest number of customers. Valve location is also necessary in the event that superchlorination is required.

Besides knowing the location of all valves, the operator must ensure that they are operational. Every valve in a water distribution system should be turned through a full cycle - open to closed to open - at least once a year.

Fire hydrants must be kept in perfect operating condition. Winter is the critical time, as freezing can render the hydrant inoperative. All hydrants should be checked during the winter and, if any are frozen, they must be thawed and the water pumped out of them. Each hydrant should be opened and let run at least once a year. This not only ensures that the hydrant works, but it also will flush out the water mains. The high velocity water will dislodge dirt, rust, and other material which accumulates in the lines. To properly flush a system, the operator should start at the hydrant nearest to the treatment plant and work, hydrant to hydrant, to the outer areas of the distribution system. Before opening any hydrant, a fire hose should be attached and run into the nearest sewer manhole. In this manner, opening the hydrant will not only flush the water mains, but the sewage collection system as well.

Occasionally, a build-up of sediment, rust, or bacterial growths which cannot be removed by flushing will occur. In these instances the line is cleaned by passing a foam swab through it. The swab is introduced at one hydrant and is forced by water pressure to the next one. This procedure, known as "pigging", is rather specialized and will not be discussed at this time.

SUPERCHLORINATION

Certain communities are troubled with the growth of living organisms in the water distribution system. These organisms, such as bacteria, algae, small crustaceans, or the larva of insects, must be killed and removed from the lines. The process involved is called superchlorination.

Superchlorination is accomplished by introducing a very strong solution of chlorine (100 to 200 parts per million) into all parts of the distribution system, leaving the solution in the lines for twenty-four hours, and then flushing the system with clean water.

Chlorine is generally available in three forms:

(1) Gas - Gaseous chlorine is used mainly for disinfecting surface water supplies for large towns and cities.

(2) Powder - Chlorine powder (calcium hypochlorite) such as "HTH" or "pittchlor" is mixed with water to form a chlorine solution.

(3) Liquid - Liquid chlorine (sodium hypochlorite) which is normally called laundry bleach (Javex, Perfex etc.) comes in a commercial grade which has 12% available chlorine.

Liquid chlorine (bleach) is the best compound to use in superchlorinating due to its ease of handling. It requires no special mixing or feeding equipment as do powder or gas. The bleach is available from most water treatment chemical suppliers.

The first step when conducting a superchlorination is to notify the residents that the water will be heavily chlorinated and unsuitable for drinking for a certain period. Written notice of the superchlorination should be mailed or distributed to every water user in the community several days ahead of time. In addition, hospitals, schools, hotels, cafes, stores and any other important business should be phoned several hours ahead as a further reminder. The notice should specify when the water will be loaded with chlorine and for how long it will be unuseable. Any other particular instructions should also be printed on the notice. A sample of the form of notice used by one community is reproduced below:

NOTICE

YOU ARE ADVISED THAT THE VILLAGE WATER SUPPLY WILL BE HEAVILY CHLORINATED FROM WEDNESDAY, DECEMBER 6, AT 6 P.M. TO THURSDAY, DECEMBER 7 AT 6 P.M. PLEASE STORE AN ADEQUATE SUPPLY OF FRESH WATER BEFORE 6 P.M. ON WEDNESDAY FOR DRINKING AND COOKING PURPOSES DURING THE PERIOD.

PLEASE RUN WATER TAPS BEFORE GOING TO BED ON WEDNESDAY UNTIL YOU ARE ABLE TO SMELL THE CHLORINE TO ENSURE THAT THE WATER LINES ARE CHLORINATED.

SORRY FOR ANY INCONVENIENCE. THANK YOU.

Council of the Village of ________________

The first step in the actual superchlorination procedure is to chlorinate any wells pumping into the system to ensure that they will not pump contaminated water into the mains during the disinfection process. The injection of bleach into the wells is quite simple. Most wells are designed such that there is access to the well through an air line which extends down to the intake screen. If the well is not equipped with an air line, it will be necessary to remove the well head to add the bleach. This is fairly easy to do for small wells, but special equipment might be required for large diameter wells with heavy well heads.

Generally speaking, one gallon of bleach will be more than sufficient to completely disinfect most wells. After the bleach has been poured into the well, the pump should be started up and left running for 30 to 40 seconds. It should then be turned off for 2 or 3 minutes. This cycle should be repeated several times to surge the chlorine and water solution out into the water bearing information.

When carrying out the superchlorination, bear in mind that the bleach is quite corrosive and therefore the air line and upper casing should be thoroughly flushed with water after the bleach is added.

After the wells have been disinfected, the next step is to chlorinate the reservoir. It may be either a ground storage tank or an elevated tower. Sufficient chlorine should be added to the reservoir so as to have approximately 100 to 200 parts per million of chlorine.

The water should then be circulated until the chlorine and water are completely mixed.

To flush the chlorinated water from the storage reservoir into the distribution system, isolate each loop of the system and open a hydrant in the loop. This releases the unchlorinated water normally in the mains and draws in the superchlorinated water from the reservoir. Blind ends that do not have a hydrant must be charged by opening up the house services at the end of the main.

Normally the chlorine is loaded into the system by starting with the areas closest to the reservoir and then working out to the farthest points. The presence of the superchlorinated water can be detected by smell or by using chlorine test papers. These test papers are available from dairy supply houses and will detect chlorine in the range of 50 to 200 p.p.m.

Another point to consider in superchlorinating the system is that all householders should run their house services until they can detect a chlorine odor. This will ensure that the service lines as well as the supply mains are disinfected.

Once the whole system has been filled with superchlorinated water, it should be allowed to stand for twenty-four hours to achieve complete disinfection. During this interval, the storage reservoir can be refilled with fresh, water so that the system may be flushed out at the end of the holding period. It may be necessary to flush out the mains several times with fresh water to remove all the traces of the superchlorinated water. If this work is done during the winter, hydrants must be are pumped dry at the end of the project.

To summarize: A water distribution system must be kept in good condition by:

(1) Repairing leaks as soon as they are detected,

(2) Maintaining an up-to-date set of "as-built" drawings,

(3) Operating each valve yearly,

(4) Flushing the water mains yearly,

(5) Opening each hydrant yearly,

(6) Conducting winter checks on all hydrants.

If this fails to keep clean, fresh water in the lines, specialized measures such as pigging or superchlorination may be required.

9. GROUND WATER AND MUNICIPAL WELLS

Rain, snow or sleet which infiltrates the soil and penetrates to the underlying strata is called groundwater. The quantity of water which can be stored sub-surface depends on the porosity of the sub-surface strata. In Alberta, about two or three percent of the annual precipitation reaches the water table. Groundwater ultimately reappears at the surface in some low area, such as a perennial slough, lakeshore, river bank or the sea shore. Springs and flowing wells are places where water issues from the earth in a visible flow. The water-bearing strata, called aquifers, may consist of unconsolidated materials like sand, gravels and glacial drift or consolidated material like sandstone, coal, shattered shale and limestone. The aquifers are either under atmospheric or artesian pressure.

Groundwater, being hidden and obscure in the ground, is often considered somewhat mysterious and subject to lingering myths. One particular myth is that groundwater is found in underground "veins", "rivers" and "lakes" and can be located by certain "gifted" persons called diviners or dowsers. So far, there has been no scientific evidence to support the theory of the diviner, but a considerable amount to dispute it. Therefore, the point emphasized is that, as far as science is concerned, water "witching" is wholly discredited. Groundwater is a natural resource that has been defined and described by geology and developed by technology.

There are two main problems in obtaining a satisfactory groundwater supply:

1. locating a permeable material with sufficient quantity of good quality water and

2. the construction of a water well which is best suited to the particular conditions.

Often, as in the case of locating a suitable groundwater supply for municipal use, the source must be available within a few miles of the community in order to be economical. Exploratory drilling will determine the best sites for extracting the groundwater within the local geologic framework, especially if the geology is complex and variable in the particular area. As the demand increases, the most common practice is to drill new wells in an effort to maintain adequate water supplies. But, what is just as important and often overlooked, is the need of communities utilizing wells to make the most efficient use of existing facilities. Often, as yields decrease, existing wells are abandoned rather than treated and redeveloped.

The following discussion will outline the basic problems associated with wells and briefly outline preventive and maintenance measures, in particular for municipal wells.

BASIC CAUSES OF WELL FAILURES AND DECLINE IN PRODUCTION

1. Underdesign:

Inadequate sizes of casing and screen are used, or selecting materials of inferior quality, merely to cut initial costs. This only saddles the owner with higher pumping and maintenance costs, as well as reduced useful life of the well.

2. Improper Construction:

a) Sand Intrusion

The most common problem is that the zone opposite the aquifer is not properly screened. Cutting-torch slots are often unsuitable in unconsolidated formations. The slots are much larger than individual sand grains, so sand can still pass into the casing. When enough sand accumulates, water no longer enters the well freely and failure results.

b) Surface Contamination

If the anulus around the casing is not sealed, polluted water, from surface drainage and/or from formations other than the aquifer in which the well is completed can move downward and cause contamination. Erosion of the overburden materials may also take place causing murky water and plugging of the well screen area. Contamination may also result from failure to seal abandoned wells.

3. Improper Development:

Basically, well development is the removal of fine particles from the formation and clearing the borehole of drilling adhesives, etc. immediately upon completion of well construction. If the well is not developed properly, eventually plugging and silting of the slots will result. The unique aspect of development is that it is one of the most important phases of the complete water well, yet is the least understood and the most abused. An underdevloped well leads to sand intrusion, inefficiency and early failure.

4. Reduced Pump Efficiency:

If considerable sand and mud is being pumped with the water due to No. 2 and No. 3 above, the pump will be subjected to abrasion and excessive wear, which reduces its efficiency. Under severe conditions, the pump may sand-lock (i.e. jamming of pump propellers). Corroded parts will cause inefficient pump operation. An increase in total dynamic head will also reduce the pump output.

5. Interference Between Wells:

When pumping takes place the water level in the well is lowered or depressed and a cone of depression radiates in a circular shape away from the well. If the cones of depression of two or more wells overlap, there is interference with one another resulting in "lower than normal" pumping levels. Interference is caused by wells that are too closely spaced or by over-pumping.

6. Bacteria Growths, Slime Deposits, Incrustations:

Bacteria and incrusting water tend to deposit organisms and minerals and cause plugging of the pores in the water-bearing formations and the openings of the well screen. Iron and sulphur bacteria are found in some ground water and produce accumulations of slimy material of jelly-like consistency, or oxidize and precipitate compounds of iron and manganese. Other forms of incrustation may occur including precipitation of carbonates and deposition of soil materials. Cases have been reported where reduction of 75 per cent in well yield has occurred in periods of three months to a year.

7. Corrosion Attack:

Corrosive groundwater will cause deterioration of well screens, casing and pumps. In particular, enlargement of screen openings resulting from removal of only a few thousandths of an inch of metal can permit an excessive amount of sand to enter the well.

8. Gas in Formation:

Surging effects and air locking of pumps may occur due to gases naturally occurring in the aquifer.

RECOMMENDED METHODS FOR DESIGN AND CONSTRUCTION OF WELLS

Sound well design and good construction practice cannot entirely be a routine process. The variability of geologic conditions - and that of groundwater occurrence within the geologic framework - are so extensive as to make each drilling operation in some degree an exploratory undertaking. However, there are basic guidelines for the water well industry. The well owner also needs to know the basic components of well technology; as this knowledge is essential for diagnosing and implementing correct well maintenance measures and well operation procedures.

1. Good Site Selection:

Unless narrow buried surficial channel deposits or fractured formations are present, or geologic control is very poor (i.e. varying permeabilities and uncorrelating strata) the groundwater available over a local area is generally somewhat uniform. "Witching" for water is not to be used as a guide for development of a groundwater source. Thus in

site selection, the following are to be considered: well interference from other wells in the area, convenience of access, and distance from potential contamination sources. Also, the well is to be located so it will be accessible for pump repair, cleaning, treatment, testing and inspection.

2. Proper Completion:

The invention of the well screen has made it possible to deal with all types of unconsolidated materials (i.e. soft sandstone, gravel, sand). Screens are selected on the basis of a sieve analysis of the water-bearing formation and the amount of water required. A screen penetrating the aquifer allows for maximum development and yield. In cases of very fine formation material, a suitable sand or gravel pack is placed between the screen and the aquifer which permits water to pass but keeps the fine sand out. In corrosive waters, it is important to use a well screen fabricated of a corrosion-resistant metal (i.e. stainless steel).

3. Sanitary Protection:

Due to irregularities in the size of the borehole and because it is necessary that the hole be larger than the well casing installed, there is some open anulus left around the outside of the casing. Watertight construction of the cased portion of a well must be carried out to prevent vertical seepage of water and/or washing of overburden material down the well. Surface casing with a bottom seal into an impervious zone must be provided. In order to ensure a positive seal, grouting of the surface casing is highly recommended. The depth of grouting around the surface casing varies with geologic and site conditions, but as a general rule, sub-surface material that is unconsolidated would be grouted to a minimum depth of 25 feet while overlying formation consisting of creviced or fractured rock, should be grouted to its full depth. Any test holes drilled should be cemented to prevent the entry of surface water and the inter-mixing of aquifers penetrated.

The top of the well casing shall terminate not less than 8 inches above ground or floor of well house. Any power-driven pump located over the well shall be mounted to form an effective seal. In the event that the pump unit is not located over the well, and the pump delivery or suction pipe emerges from the top thereof, a watertight seal shall be provided between the well casing and the piping.

4. Complete Development:

The purpose of development is two-fold: to remove all the drilling fluid and mud which may have been forced into the water bearing formation during the drilling and construction; and, to remove fine particles adjacent to the screen or perforated zone. During development, the fine particles are induced to enter the screen and at the same time accumulate the coarser particles around the outside. This

has the effect of increasing the permeability of the material in the immediate vicinity of the screen, allowing increased yield, lower intake velocity and maximum efficiency. Several different methods are employed in the development process, such as bailing, surging, jetting, backwashing and pumping.

5. Well - Transmission Line Completion:

Pitless adapter units are strongly recommended for directing water from the well heads to the feeder system. Besides their applications in offset pumping installations, pitless units are equally useful where the pump is installed in the well. Pump pits are unsanitary, subject to flooding, and cause difficulties for setting over the wells for servicing, etc.

6. Testing Wells for Yield:

In order to ascertain the yield, the safe pumping level and the potential production, a pump test is conducted on the well. The well is pumped at a constant rate and the water levels measured at specified intervals. The pump test on each production well shall be conducted at not less than its anticipated production rates. The pump test(s) shall continue for a period of time sufficient to identify any limiting boundary conditions but should not be less than 12 hours for wells intended for municipal water supply.

The use of observation wells will help determine distance-drawdown, time-drawdown effects and practical well spacings to balance partial well interference influences with costs of connecting pipelines and electrical equipment. The observation well should be permanently installed and used to monitor the production aquifer fields. Testing and interpretation of results are to be carried out under the supervision of a qualified groundwater consultant.

7. Disinfecting:

A necessary final step in well completion is thorough disinfection of the well and its appurtenances to kill any bacteria that may have been introduced during the construction operation. A chlorine solution is the simplest and most effective agent for disinfecting or sterilizing a well, pump storage tank and piping system. Highly chlorinated water for this purpose may be prepared by dissolving (powder) calcium hypochlorite, (liquid) sodium hypochlorite or (gaseous) chlorine in water. Application should be a minimum concentration of 50 mg/l, thorough mixed throughout the well for contact period of 12 hours.

MAINTENANCE AND OPERATION OF WELLS

Timely maintenance action, properly worked out to overcome specific problems in a given locality, can improve well performance and increase well life. A simple formula can not be devised that will work for every geological condition, hydrogeological condition, water quality

condition, and type of well construction. "Out of sight-out of mind" seems to be the reason to explain for inadequate maintenance of water wells. Two factors extremely important to the efficient operation of a well are: redevelopment of the well when it has declined in productivity; and the cleaning and, if necessary, reconditioning of the pump.

1. Selection of Safisfactory Pumps:

Pump selection depends on safe yield available, static head in well, pumping rate required. The main thing is to be sure that the pump is adequate to serve the particular needs, from a depth below the lowest possible drawdown at that rate. The submersible pump is the most efficient and is rapidly becoming the most popular. For pumps placed in the well, the diameter of the well casing should be two sizes larger than the nominal diameter of the pump required for the desired or potential yield, in order to avoid problems with jamming when the pump is removed for servicing.

2. Keeping Good Records of Well Operation:

Since one cannot see what is happening in the bottom of the well, he must depend on records of pumping rates, drawdown, total hours of operation, power used, water analysis, and other pertinent operating data to figure out what may be going on. A meter should be installed at the well head to record total water pumped. It is equally important that full test data (i.e. logs of geological materials encountered, depth, depth to water, length and diameter of casing, completion details, pump tests) be obtained and permanently filed when the new well and pump are initially put into operation. This background data can be extremely useful when servicing is required, also when compared to the operating data to determine continuing well and aquifer performance.

3. Acid Treatment:

Mineral deposits from incrusting type groundwater can be removed by putting strong muriatic (hydrochloric) acid into the well to dissolve the deposits. More than one treatment may be required and useful, if further improvement of the well can be achieved. The solution must be vigorously agitated and surged to force the chemical to move out into the voids of the water-bearing formation in all directions. Well screens used in this type of water should be made of corrosion-resistant metals to withstand the corrosive effect of the acid treatment.

4. Chlorine Treatment:

An effective treatment for the iron bacteria in wells is a solution of chlorine of concentration 100 p.p.m. which kills the organisms. The destruction of sulfur and slime bacteria can be accomplished by using chlorine concentration of 500 p.p.m. or more. Hydrochloric acid is often used following the chlorine treatment for the

purpose of dissolving the precipitated iron and manganese, thus making it possible to remove them from the zone surrounding the well by pumping. Again, flushing and physical agitation are important to ensure that the solution has penetrated all the well apparatus and the formation around the well.

Chlorine can also be continuously fed into the well to prevent any further growth of bacteria and to oxidize any hydrogen gas present. A chemical feeder is installed in conjunction with the pressure system. When the well pump is in operation, the chemical feeder automatically feeds chlorine solution into the well, preferably near the bottom by the pump.

5. Cleaning of Pumps:

The first indications of trouble are higher power consumption, indicating a loss in pump efficiency. This is invariably followed by reduced flows as the build-up of deposits continues. The cleaning of pumps may include: treatments with acid and polyphosphate compounds; replacement of worn parts and clearances adjusted; cleaning of pump assembly, column and shafting by brushing, scraping and flushing; rebuilding the bearing areas on the column shafting and pump shaft.

6. Gas Removal;

There is no satisfactory method for removing dissolved gases found in some aquifers to eliminate problems with pump surging, air-locking, etc. However, one means of alleviating the problem is installing a gas-trap device around the (submersed) pump. This has the effect of forcing the water to flow upward and around the mechanical device to the pump intake and helps release some gas bubbles to make their way to the surface. The top of the well casing is vented to permit the gas to escape. Aerating the water pumped to the surface prior to distribution by using the mechanical baffles will also help remove a percentage of the dissolved gas. The storage facilities and pump house should also be properly vented to prevent accumulation of gas.

LICENSING OF WELLS

All newly drilled municipal wells must be licensed with the Water Rights Branch, Alberta Environment, before the well can be used as a water source. Existing wells should also be registered, and all available information should be submitted.

The procedure for obtaining a Right to divert groundwater consists primarily of two parts:

(i) Obtaining a Preliminary Exploration Permit prior to test drilling and well construction. The permit outlines the terms, conditions and evaluations required for the particular project.

(ii) After the terms of the Exploration Permit are carried out, an application for a license is filed. Application consists of prescribed form, plan, reports, and specifications in sufficient detail to permit evaluation of alternatives, and the effect of the proposal on the aquifer(s), other existing wells and users in the aquifer well (i.e. domestic, industrial).

Once the above requirements are submitted and conditions met, a license is issued to divert and consume the groundwater. It is strongly recommended that a qualified Groundwater Consultant be retained for conducting the design, supervision, testing and interpretation of the results.

10. PUMPS

Pumps can be classified into three main categories:

A. Centrifugal Pumps

   1. Volute

   2. Diffuser

B. Rotary Pumps

   1. Gear

   2. Screw

C. Reciprocating Pump

CENTRIFUGAL PUMP

A centrifugal pump is fundamentally a very simple device, an impeller rotating in a casing. The impeller is supported by a shaft which in turn is supported by bearings. Liquid coming in at the centre (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and is thrown out by centrifugal force into the discharge.

VOLUTE TYPE PUMP

This type of centrifugal pump has a volute casing. The liquid discharges into an increasingly spiral housing. The area of the centrifugal pump volute increases from its initial point until it completely surrounds the impeller. Then it flows out to the final discharge opening. The initial section and discharge nozzle portion of the casing are separated by a wall called the tongue of the volute. The casing is proportioned to reduce the liquid velocity gradually, enabling some of the fluid's energy to be converted into static pressure.

DIFFUSER TYPE PUMPS

The flow direction of the liquid is changed by the stationery diffusion vanes. Velocity energy is then converted to pressure head from gradually expanding passages.

GEAR PUMPS

There are two basic designs of gear pumps. External gear pumps are the simplest rotary pump designs. Liquid fills the void between the gear teeth as they separate, it is carried around and forced out by the meshing of the teeth. Gears may be single, double-helical or spur teeth.

Internal gear pumps consist of one rotor with internally cut teeth meshing with an externally cut gear idler. A partition is employed to prevent any liquid from flowing back into the suction side of pump.

SCREW PUMPS

There are a large number of designs in this type of pump. Basically, these consist of one, two or more thread screws that can rotate in fixed casings. The simplest model is a single-screw pump that consists of a spiraled rotor that can turn eccentrically in a rubber internal-helix liner. Two screw pumps consist of one idler. The liquid flows between the screw threads, along the screw axis. Opposed screws may be used to eliminate end thrust in the pump.

RECIPROCATING PUMP

The word reciprocating means moving back and forth, so a reciprocating pump is one that moves liquid by a piston that moves back and forth. A simple reciprocating pump consists of a piston, an inlet valve and an outlet valve. If the piston is pulled so that the chamber is empty then the inlet valve will open and the liquid will enter the pump and fill the casing.

When the piston reaches the end of its travel and is pushed back, the inlet check valve will close, the outlet valve will open and the liquid will be forced out the exit line.

There are two distinct types of pumps which have their own particular characteristics:

a) Positive displacement pumps

b) Non-positive displacement pumps.

Non-positive displacement pumps are classified as centrifugal and turbine. When starting this type of pump make sure the suction valve is open. If it is necessary to control rate of discharge, throttle the pump on the discharge side. Running a centrifugal pump with a closed suction valve causes the pump to suffer from cavitation with the result that erosion of the pump impeller will result.

Positive displacement pumps. The following come under this type: gear types, diaphragm, rotary, plunger, reciprocating.

Positive displacement pumps can produce very high pressures. For example boiler feed pumps work from 50 to 3000 P.S.I and more. Reciprocating pumps have suction and discharge valves while most of the rotary pumps do not need valves built into the pumps so that they will operate. However, when they are installed nearly all pumps have isolating valves, usually a gate valve on the suction and a gate valve on the discharge line of the pump.

It is very important to remember that when starting a positive displacement pump, the discharge side must be open. If the pump is started with the discharge valve closed it will develop sufficient pressure against the closed valve and damage the pump motor and starter. In some cases pipes have been split open by this procedure. It is also necessary to open the suction valve before the pump will deliver any fluid.

MAINTENANCE

Proper maintenance is the key to obtaining long life and satisfactory performance from your pump. The following are a few important factors to consider:

1. Make certain that the pump operates under the condition it is designed for.

2. Establish a proper maintenance schedule and follow it to the letter.

3. Lubrication of pumps should be in the strict accordance with the recommendations of the manufacturer.

4. Personnel should be qualified and experienced in maintenance work. Knowledge of such important factors as what constitutes excessive vibration, when bearings should be replaced, glands re-packed, what is a loose fit, when does welding constitute a safe repair, and similar points.

5. Knowledge of your equipment may be obtained from instruction manuals issued by the manufacturer. These manuals are the result of many years of experience and research on their part. So to look after equipment correctly, the manuals are a must.

SECTION C

WASTEWATER

11. MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS

The sewer and drainage system of a community is one of its most important and expensive assets. If the system is allowed to deteriorate, its useful life is shortened, its overall dollar value is lowered, public health hazards may develop and damage to private and public property can occur. To properly maintain the sewer and drainage system, Preventative maintenance should be practised.

Preventative maintenance is a systematic program of cleaning, inspection and repair that keeps breakdowns and failures of the system to a minimum. Inspecting, cleaning and repairing the system after it has failed is more costly in terms of dollars and public inconvenience than a preventative maintenance program.

A good preventative maintenance program would include: record keeping, inspections, cleaning and thawing of the system, and a safety program.

RECORDS

An accurate set of records is essential for an effective sewer maintenance program. A detailed set of "as-built" plans for the entire sewer and drainage system should be kept. These should indicate such things as: size of pipe, type of material, depth, grade, age, line length, invert elevations and manhole details. If separate storm and sanitary systems exist this information should also be shown. A record of the locations and details of all other utilities should be kept since this will prove valuable if a dig-up of a sewer line is required. The plans should always be kept up to date with any additions or modifications indicated as soon as they are completed.

In addition to an accurate set of construction record plans, it is important to keep a record of all sewer maintenance performed on the system. Operations such as cleaning, flushing and inspection should be recorded. Also, complaints from the public regarding backups or flooding should be recorded along with details of the action taken to rectify the trouble. These types of maintenance records are very important in planning future modifications to the system.

INSPECTION

There are arguments both for, and against, a routine inspection of a sewerage system. In cases where lines are relatively new and are not causing any problems, a routine yearly inspection is of little use. Where older lines exist or where lines have caused trouble in the past, routine inspection is essential and may have to be performed more frequently than on an annual basis. Inspections may be combined with flushing and cleaning operations.

CLEANING SEWERS BY FLUSHING

In the operation and maintenance of a sewer system the systematic procedure of low pressure or gravity flushing is useful in keeping the system operating efficiently. This procedure involves connecting a hose to the nearest fire hydrant and dumping the water into a manhole along the line in question. The manhole should be at the upper end of the line. The maintenance men then follow the flow down through the system by lifting each manhole cover on the line. Being familiar with the particular main, they can determine whether the flow is sluggish or whether an excess amount of unusual solids is present. This visual checking of the flow should tell the operator whether the line needs cleaning or whether there is something in the line obstructing the water. This procedure constitutes part of the inspection of the system.

This type of flushing operation is particularly successful on lines which normally have a very low flow such as at the high end of a line. The low flow results in low velocities in the line which in turn contribute to sediment build-up. Flushing merely increases the velocity and thus tends to remove the debris. Since it is transported down the line, sooner or later the debris will have to be removed, whether at the treatment plant or by collecting and removing it at a manhole.

CLEANING SEWERS BY RODDING

There are two basic types of rodding machines currently in use: the bucket rodders and the power rodders.

The bucket rodding machines have been around for some time and work well in cleaning sewers. These are the cable type machines where a bucket is winched through the mains. They are capable of removing almost any type of debris in the lines including roots. Various sizes of buckets, cutters, and steel brushes are available to ensure a complete cleaning. The only drawback with this type of operation is that it is slow.

In cases where a line blocks suddenly, a power rodder using flexible steel rods is generally used. There are two basic types of these rodders; the small lightweight, cart mounted machines using sectional steel rods and the large truck or trailer mounted units using a continuous rod. The small units are able to handle the majority of routine mains as well as rip out light to medium densities of roots. They also have an advantage over continuous rodders in that if there is a blockage, and the roads are impassible, these units can be carried in and the blockage removed.

The large continuous rodders, however, have several advantages over the small machines. They have considerably more power and this enables the rod to be pushed in faster and with greater twisting torque. Since the rod is continuous it does not require coupling or uncoupling.

The bucket rodding machines and the continuous power rodders are fairly expensive but should be within reach of large towns and small cities. Owning equipment is advantageous because it is immediately available if a problem arises. Small communities, however, may have to depend on the resources of contractors in which case their services may not be as immediate as would be desired. With this in mind, a community which is unable to efficiently own and use some of the more complex rodders should at least own a small power rodder with the sectional steel rods. In this way they are able to take care of most situations.

CATCH BASINS

The need for cleaning catch basins depends on the type of construction. If the catch basin is built without a sump, no cleaning is needed as solids continue straight out to the main. A condition such as this would incur higher maintenance costs of the mains. If the catch basins have sumps, then they can be cleaned with shovels and buckets, or spoons, or they can be pumped out using a pump truck. How often a catch basin should be cleaned depends on how long it takes for the sump to fill up. Some areas may require monthly cleaning, others yearly. In any case, they sould be cleaned in the fall so that they are ready to take the spring run-off without trouble.

THAWING

The thawing of culverts and catch basins is one of the things a sewer maintenance staff must contend with in the Prairies during spring run-off. Steam is required for this operation and there are two basic types of machines available for this purpose. There are the high pressure, skid mounted coal or propane fired boilers and the small low pressure skid fueled steamers which are usually referred to as "Jennies". The high pressure boiler produces a very hot dry steam, but a steam engineer is required to operate it. Long, difficult culverts are thawed easily by these large boilers. The Jennies produce a much wetter steam which is less effective, but no special permits are required to operate them. They have advantages in that they have a very fast start up time, and being on relatively small trailers, they are easily handled in traffic. The larger boilers have to be mounted on a large truck.

At any time from about January 15th, to at least the end of April, freezing may occur in any part of the system. When freezing occurs, the street sewer or service connection is usually completely blocked with ice. The depth of frost penetration is indicated by a ring of frost that occurs in the manholes. When the frost ring reaches the sewer itself, trouble can be expected. Usually a service connection that is in good condition will not freeze as long as the street sewer itself is kept flowing. If certain parts of the system are giving trouble with freezing, they should be watched very closely at this time of year. If the sewer seems to be slowing up, it is a good idea to give this part a flushing from either a hydrant or a water truck. This will save a lot of trouble later.

In any area that is persistently bad, the possibilities of either filling the street or re-laying and deepening the sewer should be checked into during the summer. It is usually cheaper to re-lay the sewer than to thaw every winter.

Street Sewers in sandy soil, during a normal winter, are generally safe with about 6 1/2 to 7 feet of cover, but if the flow is small and the grades are fairly flat, trouble may be experienced even down to 8 1/2 to 9 feet. Correct grades and uniform alignment are very important. For an eight inch sewer the minimum should be .4% or 4/10 ft. per 100 feet. It will be found that a .3% or 3/10 ft. per 100 feet will give some trouble if the flow is small. It is amazing the differance that a mere 1 1/4 inches per 100 feet can make.

DITCHES

Most communities and municipalities have drainage ditches to maintain. These should be cleaned and regraded at least once a year. In conjunction with this, culverts and their entries should be checked and repaired if necessary.

STORM SEWER OUTFALLS

All storm outfalls should be inspected periodically for excessive erosion or other damage. Most storm systems carry a certain amount of infiltrated ground water. During the winter months, the outfalls can be closed off by ice due to this ground water freezing. It is therefore essential that these outfalls be checked throughout the winter and kept open in case a sudden thaw should occur.

SAFETY

Safety should always be kept at the top of every Sewer Maintenance Program. Conditions are always changing and the maintenance man should be ready for them. Some of the most important conditions are:

1. Before entering a manhole, check for gases or lack of oxygen.

2. Never go down a manhole alone. Always have someone backing you up at the top.

3. Wear a harness and rope.

4. Have the following equipment on hand at all times:

    a) Explosion Meter.
    b) Oxygen Deficiency Meter.
    c) Hydrogen Sulphide Tester.
    d) Self Contained breathing apparatus.
    e) Flags, signs, barricades, flares.
    f) Approved first aid kit.

It is imperative that all Safety Regulations set by the Worker's Compensation Board be followed and that the men doing the work be thoroughly familiar with their equipment.

The main thing to keep in mind is that a well laid out program of Preventative Sewer Maintenance always pays off. If in doubt about anything, at any time, always contact somebody who may help you.

12. OPERATION AND MAINTENANCE OF LAGOONS

Sewage lagoons are the most widely used method of sewage treatment in Alberta. Lagoons are commonly known as sewage ponds, oxidation ponds or stabilization ponds.

Proper operation and maintenance of lagoons is an important part of an operator's job.

LAGOONS

Sewage lagoons are classified into two groups: anaerobic ponds and aerobic ponds. Anaerobic ponds are intended to operate with approximately 10 feet of liquid in them. They usually have a detention period of 2 to 4 days. Aerobic ponds are generally much larger. They operate with a depth of about 5 feet of liquid. These ponds have a holding period of 6 to 12 months. After the storage time the effluent is discharged to a drainage course.

During detention in the ponds sewage is broken down into stable compounds by physical and biological processes. Contrary to the beliefs of many laymen, effluent from a sewage lagoon has, in most cases, treatment equivalent to primary or secondary treatment, depending on the detention period.

It is important to maintain a lagoon in order to eliminate potential health hazards. In too many cases, municipal sewage is simply forgotten after it enters the sewers.

The most obvious tasks are to keep the fences in good repair and to keep the weeds and grass cut. The berms should be mowed several times a year. The growth of weeds such as cattails along the edges of ponds is an ideal environment for mosquito breeding, therefore these weeds should be removed yearly. The best time to remove them is just after the lagoon has been drained. In cases where the lagoons have constant overflow the best time would be in the fall when the ground is frozen but before there is snow cover. It is not recommended that chemicals be used for weed control since they will eventually be discharged into a drainage course where they may cause problems. Also, chemicals may interfere with the stabilization process of the sewage.

Fences and gates should be kept in good repair at all times. It is important to keep small children and things such as snowmobiles away from the ponds.

Berms should be checked for leakage periodically, probably once every month or so. Animals, such as muskrats, can cause problems by burrowing into the berms.

Overflow structures, manholes, drainlines and valves should be checked periodically. Valves should be well marked in case they need to

be opened or closed in emergencies or so that they can be easily found in the winter.

In many lagoons the build up of sludge near the inlet could cause problems. Facilities with anaerobic ponds can bypass the first pond for a period of six months to a year. It may be the case that the system has two or more anaerobic ponds that can be used interchangably. During the period that a pond is by-passed, the sludge will decompose and stabilize. The addition of lime will speed up this process.

In cases where a pond cannot be by-passed, a high-pressure water stream can be used to dispurse the sludge. If the sewage inlet is not near the berm this could cause some difficulty. It may be necessary for the build-up to be removed by dragging a cable back and forth across it, or by using a boat to provide access to the build-ups. Then, they can be dispersed by hand. The addition of line at a lift station or manhole will help to control sludge build-up as well as helping to control odors.

It is important to remember that a sewage lagoon is a treatment facility and it must be operated and maintained on a regular basis.

13. PRIMARY WASTEWATER TREATMENT

Primary treatment has no precise meaning, but is usually taken to mean the removal of pollutional matter by mechanical means, i.e. - by screening, by settling or by flotation in a settling tank. Thus primary treatment will remove all large debris, grit and any materials which will settle or float thus leaving the colloidal, dissolved and liquid impurities.

SCREENING

Sewage flowing into the treatment plant will occasionally contain pieces of wood, roots, rags and other debris. To protect equipment and reduce any interference with in-plant flow, debris and trash are usually removed by a bar screen. Most screens in treatment plants consist of parallel bars placed at an angle in a channel in such a manner that the sewage flows through the bars. Trash collects on the bars and has to be periodically raked off by hand or mechanical means.

MANUALLY CLEANED BAR SCREENS

Manually cleaned bar screens require frequent attention. As debris collects on the screen, it blocks the channel, causing the sewage to back up into the sewer. This, in turn, causes organic materials to settle out; the dissolved oxygen is depleted and septic conditions develop, producing hydrogen sulfide which causes a rotten egg odor and is corrosive to concrete, metal and paint. If cleaning of the screens is infrequent, the sudden rush (when they do get cleaned) of septic sewage creates a sudden "shock" load on the plant, sometimes resulting in a poor quality plant effluent.

MECHANICALLY CLEANED SCREENS

Mechanically cleaned screens overcome the problem of wastewater backing up and greatly reduce the time required to take care of this part of the plant. There are various types of mechanisms in use, the more common being travelling rakes which bring the debris up out of the channel and into hoppers or other receptacles. These units should be well lubricated and adjusted. Manufacturers recommendations should be followed carefully. A few minutes spent in proper maintenance procedures can save hours or days of trouble and help to keep the plant operating efficiently.

Occasionally, some debris will be present which the equipment cannot remove. Periodic checks should be made so that these materials can be removed by hand. To determine if some material is stuck in the screen, the flow may be diverted through another channel or the screen may be probed with a rake or similar device.

DISPOSAL OF SCREENINGS

The material removed from the screens is very offensive and hazardous. It produces obnoxious odors and attracts flies. Burial, shredding or grinding are common methods of disposal. If the screenings are buried, at least six inches of earth cover must be provided immediately. The final earth cover must be deep enough to prevent flies from reaching the screenings through cracks caused by setting. At small plants with manually cleaned bar screens, an enterprising operator can make a "press" from a piece of steel pipe or casing, using a heavy screw, rack and pinion, or even an automobile jack to provide pressure, to dewater the screenings before disposal. The practice of using grinders (shredders, disintegraters, etc.) to cut up screenings and return them to the effluent can impose a heavy load on the treatment processes that follow. It also seems silly to put back in, even in a modified form, something that has already been taken out.

COMMINUTION

Comminutors are devices which act as a cutter and a screen. Their purpose is to shred (comminute) the solids and leave them in the wastewater. This overcomes problems of screenings disposal. As with the screens, they are mounted in a channel, and the wastewater flows through them. The rags, etc., are shredded by cutters (teeth) until they can pass through the openings. Pieces of wood and plastic are rejected and must be removed by hand. Most of these units have a shallow pit in front of them to catch rocks and scrap metal. The flow to the comminutor should be shut off periodically and the debris removed from the trap. The frequency of checking the trap can be determined from experience. However, it is not good practice to allow more than a few days between checks.

There are many variations of the comminutor. One of the more common ones has the trade name of "barminutor". This unit consists of a bar screen made of U-shaped bars and a rotating drum with teeth and "shear bars". The rotating drum travels up and down the bar screen.

GRIT REMOVAL

Grit (sand, eggshells, cinders, etc.) is the heavier mineral matter in wastewater which will not decompose or "break down". It causes excessive wear in pumps. A mixture of grit, tar, grease and other cementing materials can form a solid mass in pipes and digesters that will not move by ordinary means. Consequently, grit should be removed as soon as possible after reaching the plant.

GRIT CHAMBERS

The simplest means of removing grit from the wastewater flow is to pass it through channels or tanks which allow the velocity of flow to be reduced to a range of 0.7 to 1.4 ft./sec. The objective is to allow the grit to settle to the bottom, while keeping the lighter organic solids

moving along to the next treatment unit. Experience has shown that a flow-through velocity of one foot per second (ft./sec.) is best.

Methods of removing the grit vary from a hand shovel to various types of mechanical collectors and conveyors. For hand-cleaned chambers, the frequency of cleaning is determined by experience. If the channel can be removed from service during the cleaning operation, the job is made easier, and no grit is washed into the plant.

Since there is always a small amount of organic matter in the grit chamber, disposal of grit should be treated the same as screenings. Burial is the most satisfactory disposal method. Failure to quickly cover grit results in odors and attracts flies.

There are many types of mechanical grit collector mechanisms. Common ones are chain-driven scrapers (called "flights") that are moved along the bottom and up an incline out of the water to a hopper, or along the bottom to an underwater trough where a screw conveyor lifts the grit to a storage hopper or truck. Some designs use conveyor belts with buckets attached.

An aerated grit chamber is actually a tank with a sloping bottom and a hopper or trough in the lower end. Air is injected along the wall of the tank above the trough. The rolling action of the water in the tank moves the grit along the bottom to the grit hopper. Grit is removed from the hopper by a conveyor system.

Aerated grit chambers are most frequently found at activated sludge plants where there is a readily available air supply, and the pre-aeration helps to "freshen" the wastewater. The older wastewater becomes, the more difficult it is to treat. A freshening process tends to make the following processes more effective.

A grit chamber with a slower flow velocity than recommended may allow appreciable organic matter to settle out with the grit. This mixture of grit and organic matter is called detritus. In some plants, grit chambers are called detritus tanks. Organic matter may be separated from the grit by blowing air through or washing the detritus to re-suspend the organic matter. Centrifuges also are used to separate grit from sludge or organic matter from grit.

GRIT WASHING

In some cases it is necessary or desirable to use grit as fill material. Since a small amount of organic material settles out with the sand, etc. it becomes necessary to "wash" the grit. There are a number of devices built for this purpose. Most use water to wash the grit as it is being removed from the grit chamber. In aerated grit chambers, the grit is ordinarily free enough of organics that it may be considered "washed".

FLOW MEASURING DEVICES

Although flow measuring devices are not for treating wastes, it is necessary to know the quantity of wastewater flow so adjustments can be made on pumping rates, chlorination rates, aeration rates, and other processes in the plant. Flow rates must also be known, for calculation of loadings on treatment processes and treatment efficiency. Most operators prefer to have a measuring device at the headworks of their treatment plants.

The most common measuring device is a Parshall Flume. Basically, it is a narrow place in an open channel which allows the quantity of flow to be determined by measuring the depth of the wastewater. Because its smooth construction does not offer any protruding sharp edges or areas where wastewater particles may catch, or collect behind the metering device, it is relatively problem free.

Another measuring device used in open channels is a weir. A weir is a wall placed across the channel over which the waste may fall. It is usually made of thin metal and may have either a rectangular or V-notch opening. Flow over the weir is determined by the depth of waste going through the opening. A disadvantage of a weir is the relatively dead water space that occurs just upstream of the weir. If the weir is used at the head end of the plant, organic solids may settle out in this area. When this occurs, odors and unsightliness can result. Also, as the solids accumulate the flow reading may become incorrect.

A good measuring device for flows of treated or untreated wastewater is a Venturi meter. It is a special section of contracting pipe, and it measures flow in much the same way as a Parshall Flume. It does not offer any sharp obstructions for particles to catch on. Magnetic flow meters are also being used successfully to measure wastewater flows.

SEDIMENTATION

In this process the waste is directed into and through a large tank or basin. Flow velocity in these tanks is reduced to about 0.03 ft. per second, allowing the settleable solids to fall to the bottom of the tank, thus making the wastewater much clearer. It has therefore become common practice to call these sedimentation tanks "clarifiers".

Primary clarifiers normally are either rectangular or circular and are usually designed to provide 1.5 to 2 hours detention time. Generally, longer detention times provide more solids removal. In a tank with two hours detention time, approximately 60 percent of the suspended solids in the raw wastewater will either settle to the bottom or float to the surface and be removed. Removal of these solids usually reduces the Biochemical Oxygen Demand (B.O.D.) of the waste approximately 30 percent. The exact removal depends on the amount of BOD contained in the settled material.

All primary clarifiers, no matter what their shape, must have a means for collecting the settled solids (called sludge) and the floating solids (called scum). In the rectangular tanks, sludge and scum collectors are usually wooden beams ("flights") attached to endless chains. The collector flights travel on the surface, in the direction of the flow, conveying grease and floatable solids down to the scum trough to be skimmed off to the solids (sludge) handling facilities. The flights then drop below the surface and return to the influent end along the bottom, moving the settled raw sludge to the sludge hopper. The sludge is periodically pumped from the hopper to the sludge handling facilities.

In circular tanks, scrapers or "plows" attached to a rotating arm, rotate slowly around the bottom of the tank. The plows push the settled sludge towards the center and into the sludge hopper. Scum is collected by a rotating blade at the surface. As in the case of the rectangular tank, both scum and sludge are usually pumped to the solids or sludge handling facilities.

The clear surface water of the primary tank flows out of the tank by passing over a weir. The weir must be long enough to allow the treated water to leave at a low velocity; if it leaves at a high velocity, particles settling to the bottom or those already on the bottom may be picked up and carried out of the tank.

Some typical removal efficiencies for primary clarification are as follows:

	Expected Removal Efficiency
Settleable solids	90% to 95%
Suspended Solids	40% to 60%
Total Solids	10% to 15%
Biochemical Oxygen Demand	25% to 35%
Bacteria	25% to 75%

Clarifier efficiencies are affected by many factors, including:

1. Types of solids in the wastewater, especially if there is a significant amount of industrial wastes.

2. Age of wastewater when it reaches the plant. Older wastewater becomes stale or septic, and solids do not settle properly because gas bubbles form under them.

3. Rate of wastewater flow.

4. Mechanical conditions and cleanliness of clarifier.

14. OPERATION AND MAINTENANCE OF WASTEWATER LIFT STATIONS

DESCRIPTION OF SEWAGE LIFT STATIONS

Sewage lift stations are installed where sewage cannot flow to the main interceptor or sewage treatment plant by gravity. The modern lift station is a highly mechanized structure that will function normally day after day with little attention.

There are three basic arrangements for sewage lift stations:

A. Wet-well-dry-well	-	for installations having a flow of 200 g.p.m. or more.
B. Wet-well mounted	-	for installations having a flow of 200 g.p.m. or less.
C. Manhole lift stations	-	for installations having flows of less than 50 g.p.m.

Lift stations have two pumps each sized to handle 100 to 150 percent of the maximum flow. Centralized pumps are common for wet mounted lift stations. They may be either submersed in the wet-well with the drive above the liquid level or the entire pump can be mounted above the wet-well with a vacuum priming system.

The pumps are designed to pump 6 to 7 times an hour during normal conditions, but never less than once every 30 minutes during low flows. The pumps should be wired so that they automatically alternate. This will give uniform wear and ensure that there is a working standby unit. The pumps should have clocks on them to give the length of time they have operated. There should be one time clock for each pump and one for the pumps when they are operating together.

The wet well is sized so that it will provide approximately 10 minutes retention of average flows. The bottom slopes are at 45 degrees to ensure settling of solids near the pump inlet.

The control system for a two pump lift station usually consists of a four level control. One control is set to stop the pump, one to start a pump, a higher one to start the second pump and a higher one yet to sound an alarm that the lift station cannot handle the flows. The most popular controls are Flygt bag, sealtrodes or bubbler systems.

The dry-well should be equipped with a sump pump to handle any leakage or seal water.

SEWAGE LIFT STATIONS VENTILATION

The purpose of ventilating sewage lift stations is to reduce the level of any noxious gases and/or vapors to a point where they are not

directly or indirectly injurious or destructive to the life of human beings. If they are present, hazards from burns, explosions, asphyxiation or poisoning exists.

Mechanical ventilation is required in both the wet well and dry well of all sewage lift stations. In pits over 15 feet deep, multiple inlets and outlets are desirable. Fine screens, or other obstructions in the air ducts should be avoided in order to prevent clogging. Switches for the ventilation equipment are to be conveniently located, marked and incorporate an indicator light.

A. Combination "Wet and Dry Well" Lift Station:

Wet Wells - Ventilation must be continuous and must provide at least six complete air changes per hour. The well is to be isolated from the rest of the station. Fresh air is to be forced into the well at a point six inches above the normal operating water level and allowed to escape through vents, to the atmosphere from a point immediately below the operating floor.

Dry Wells - Ventilation is to be continuous and must provide at least six complete air changes per hour. Fresh air is to be forced into the well at a point six inches above the pump floor and allowed to escape through vents in the roof of the superstructure.

Fresh air inlets are to be kept remote from control equipment or water lines in order to prevent freezing. Heating of cold air during winter is required.

B. Wet Well Lift Stations:

Ventilation is to be continuous and must provide at least six complete air changes per hour. Fresh air is to be forced into the well at a point six inches above the normal operating water level; and allowed to escape through roof vents, to the atmosphere.

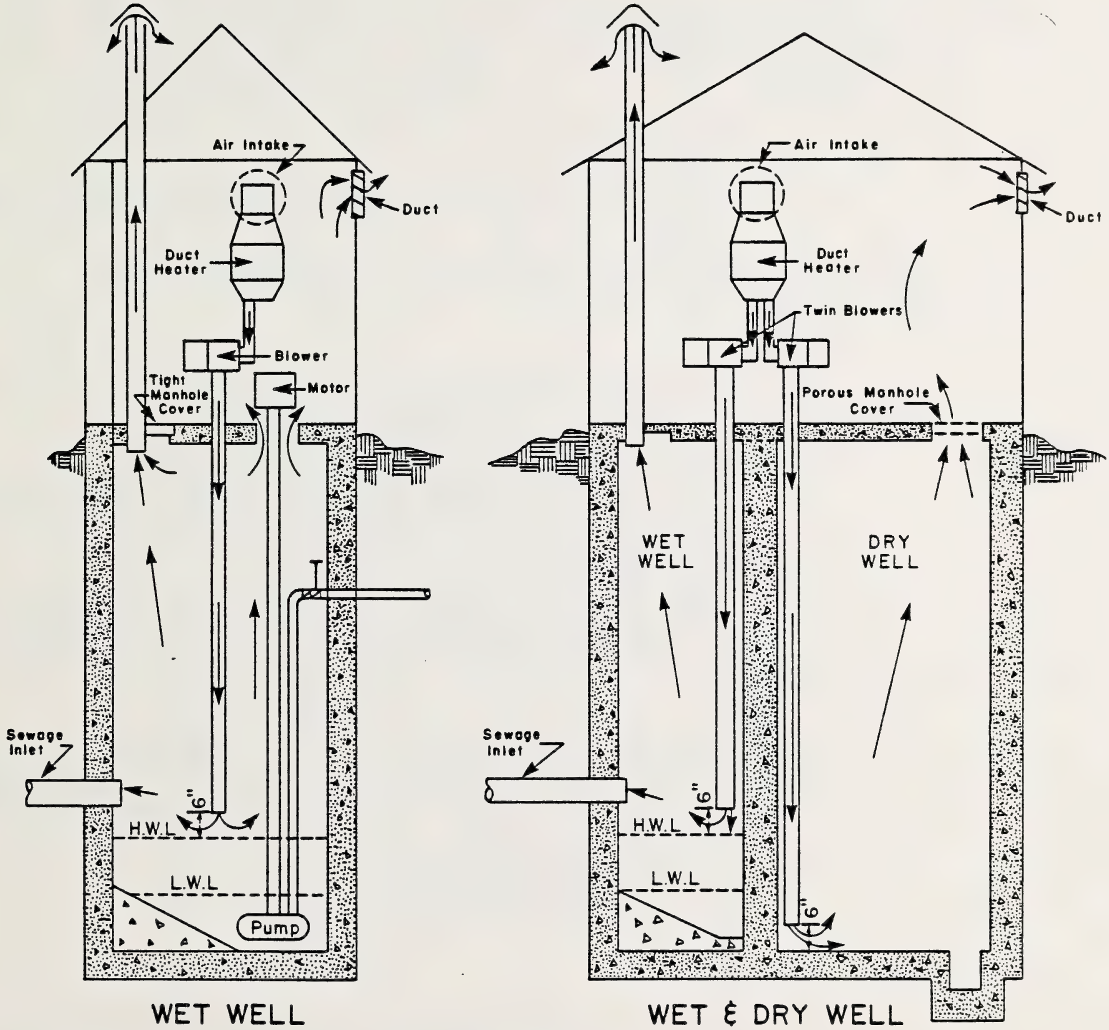
Fresh air inlets are to be kept remote from control equipment or water lines in order to prevent freezing. Heating of cold air during winter is required.

C. Manhole Lift Stations:

Small manhole type lift stations will be considered for a restricted number of services. Ventilation may be intermittent and provide at least six air changes per hour. Fresh air is to be forced into the manhole at a point six inches above the normal operating water level.

MAINTENANCE AND INSPECTION

A good maintenance and inspection program is important for the proper operation of a lift station. Lift stations should be inspected



WET WELL

WET & DRY WELL

REQUIREMENTS

a) Continuous Ventilation

b) Six Air Changes Per Hour

c) Fresh Air Heated

Alberta ENVIRONMENT	POLLUTION CONTROL DIVISION
SUBMITTED .... DATE .... / DESIGNED .... CHECKED	VENTILATION OF LIFT STATIONS
APPROVED .... DATE .... / DRAWN S. Y. C. CHECKED	SCALE N. T. S. / SHEET OF / DATE DEC. 1979 / DRAWING No

daily and records kept of each visit. Manufacturer's maintenance and operating manuals should be kept in the lift stations and referred to frequently.

A. Daily Inspection:

Wet Well:

1. check if venting is operating
2. clean screens
3. check floats or control system. Untangle and clean away any debris or grease. Manually operate the controls if possible, and
4. check to see if there is a grease build-up.

Dry Well:

1. check ventilation
2. check motors for vibrating or heating
3. check packing for leaking or heating
4. check bearing for vibrating, heating or noise
5. start each pump - if they start slow they are probably plugged - if they vibrate when started the suction could be plugged
6. check sump pump
7. clean lift station
8. make records - recording time on time clocks, conditions in wet-well and dry-well and any maintenance performed.

B. Monthly:

1. Clean wet-well by removing any grit which has accumulated on the bottom. Remove any grease which has accumulted on the sides or surface. If a hose is used for cleaning, remove it from the wet well before turning it off
2. check pump discharge pressure
3. inspect check valves, and
4. check capacity of pumps (see example).

C. Yearly:

1. Have an electrician inspect wiring, and switch gear, should also check power draw and phasing on the pumps,
2. paint lift station
3. lubricate (usually annual). All lubrication should be done according to the manufacturer's specifications. Do not over lubricate.

If a lift station has no flow metering then the capacity of each pump should be checked monthly by a pump draw down test. To perform the test, first the level of liquid in the wet well should be recorded, a pump started and operated for a fixed length of time and liquid level in

the wet well again recorded. Then record the time required to refill the wet well knowing the surface area of the wet well and the amount of draw-down, the volume of liquid pumped can be calculated. The volume in gallons divided by the time in minutes gives the apparent pump capacity. Next divide the volume by the time it took to refill the wet well. This gives the refill rate and adding this to the apparent pump capacity yields the actual pump capacity.

<u>EXAMPLE:</u>

Pump Drawdown Test

A lift station with a square wet well, 10' x 10', is pump tested. The pump is operated for 5 minutes and the draw-down in the wet well is 2 feet. It then takes 10 minutes for the wet well to refill that 2 feet.

Pump operated for 5 minutes

Refill takes 10 minutes

1 cubic foot = 6.24 Imperial Gallons

Area of wet well = 10 x 10 = 100 square feet

Volume pumped = 100 x 2 = 200 cubic feet

or 6.24 x 200 = 1,248 gallons

Apparent pumping rate:

$\frac{1,248}{5}$ = 249.6 Imperial gpm or approximately 250 i.g.p.m.

Refill rate:

$\frac{1,248}{10}$ = 124.8 i.g.p.m. or 125

Actual Pumping rate:

250 + 125 = 375 i.g.p.m.

SECTION D

MATHEMATICS

15. FUNDAMENTAL FORMS

There are basically only 8 forms of questions to be dealt with in simple mathematics. Once 8 forms are mastered, as to the process required for solving, then all types of questions can be done.

The 8 forms which should be internalized are:

a) $6 + n = 10$

Subtract - $(10 - 6 = 4)$

n is unknown. We all know the answer is 4, but what we are looking at is the form. When we know one part quantity, and a total quantity, we SUBTRACT to find the other part quantity.

b) $n + 6 = 10$

Subtract - $(10 - 6 = 4)$

As above

c) $6 - n = 2$

Subtract - $(6 - 2 = 4)$

Here, we see that a total less an unknown gives us a new total. To find the part taken away, we subtract the new total from the old total.

d) $n - 8 = 4$

Add - $(8 + 4 = 12)$

Here, we are given a new total, and told how much was taken from the old total (n). To find that old total, we must add the new total to the amount taken from the old.

e) $6 \times n = 18$

Divide - $(18 \div 6 = 3)$

Here, to find out how many groups of 6 are in 18, we must divide the total, 18 by 6 -- one of its factors.

f) $n \times 3 = 18$

Divide = $(18 \div 3 = 6)$

Same as above

g) $24 \div n = 6$

Divide - $(24 \div 6 = 4)$

Here we must divide the total by its factor, 6, to obtain its other factor, 4.

h) $n \div 5 = 6$

Multiply - $(5 \times 6 = 30)$

Here we know that we have 5 groups, with 6 in each. Therefore, to find out how many items we had to begin with, we multiply the 6×5 to get 30.

These are 8 forms of questions constantly recurring in math. Other types of questions, whether fractions, decimals, mixed numbers, etc. can all be solved if we understand the processes of those types, and the 8 forms just given.

16. WHOLE NUMBER OPERATIONS

INTRODUCTION

There are four basic operations in math. These are addition, subtraction, multiplication and division.

ADDITION

The addition of whole numbers is based on a system where groups of 10, 10^2, 10^3, etc. are collected together into new, larger groups.

Example 1: 465 +814 +347 = 1626

(10^4) 10,000	(10^3) 1,000	(10^2) 100	10	1

Here we see in example 1 the base 10 chart. We work on an assumption that groups of 9 are all we can collect in each column. If we can make 10 or more of one column's units, then we regroup into larger units.

For example:

1000	100	10	11
	1	1	
	4	6	5
	8	1	4
	3	4	7
1	6	2	6

Adding the numbers above, we get 16 ones, regrouped as 6 ones and 1 ten; 12 tens, regrouped as 2 tens and 1 hundred; and then 16 hundreds, regrouped as 6 hundred and 1 thousand.

Practise in Addition

1. 27 + 41 + 80 + 13 = ____________

2. 56 + 9 + 34 + 78 = ___________

3. 15 + 63 + 22 + 26 + 40 = _____________

4. 689 + 371 + 508 = __________

5. 267 + 155 + 438 + 77 = __________

6. 326 + 307 + 411 + 193 = _____________

7. t - 834 = 1,096   t = ___________

SUBTRACTION

Subtraction is also, of course, based on the same base 10 chart. Here, the only complicating factor is the borrowing of values when needed.

For example:	824 - 213 611	Straight forward 4 ones minus 3 ones = 1 one 2 tens minus 1 ten = 1 ten 8 hundreds minus 2 hundreds = 6 hundreds

However, when borrowing is needed, we must sometimes "get more of a unit from a larger unit.

For example:	726 - 8 718	Here, we must borrow one group of 10 from the 2 tens, leaving 1 ten. Then the 6 become 16 ones. Now we can take 8 from 16 and have 8 left.

Sometimes, borrowing across a 0 can cause problems.

For example:	399 ~~4~~~~0~~~~0~~8 - 279 3729	To do this, we need more ones, tens, and hundreds than we have in our larger group We borrow from the 1,000 column. This gives us 10 hundreds, but we borrow one of the hundreds which leaves 9 hundreds and gives us 10 tens. Now we borrow 1 ten, have 9 left, and get 18 ones. Then it is easy.

Practise in Subtraction

1. 5,210 - 4,733 = ______
2. 728 + n = 900   n = ______
3. 1,364 - c = 687   c = ______
4. z + 2,306 = 4,008   z = ______
5. 3.149 + n = 6,232   n = ______

MULTIPLICATION

Multiplication is a short form of repreated addition. 6 x 5 really says 6 + 6 + 6 + 6 + 6, or 6, fives times. The advantage of multiplication over addition can readily be seen in this question -- 712 x 814 = . This can be done in about 4-6 steps by multiplying, or in 817 steps by adding (814 in writing it out, plus 3 in adding each column).

For example: Process 6 x 5 = 3-

6 ones repeated 5 times = 30 ones or 3 tens

For example: 712 x 814

A		B	
712		712	
x 814		x 814	
2,848		8	(4 x 2)
7,120		40	(4 x 10)
569,600		2,800	(4 x 700)
579,568			
		20	(10 x 2)
		100	(10 x 10)
		7,000	(10 x 700)
		1,600	(800 x 2)
		8,000	(800 x 2)
		560,000	(800 x 2)
		579,568	

Example A shows the usual multiplication process. B shows what is really happening as we multiply. A is faster, and just combines the parts seen in B.

Practise in Multiplication

1. 4 x 509 = ________

2. 73 x 25 = ________

3. 828 x 7 = ________

4. 6 x 5,080 = ________

5. 49 x 84 = ________

6. 26 x 703 = ________

DIVISION

In division, we reverse the multiplication process. Instead of "how many is 6 groups of 2?", we say:

a) "How many groups of 6 in 12?" (12 ÷ = n) 12 - 6 ≑ 2

b) "How many groups of 8 in 35?" (35 ÷ 8 - n) 35 ÷ 8 = 4 3/8.

a)
```
     2
  6/12
    12
     0
```

6 goes into 12 two times, 6 x 2 = 12, when 12 is subtracted from 12, we get 0 as a remainder.

b)
```
    4          35 ÷ 8 = 4 3/8
 8/35
   32
    3
```

8 goes into 35 four times, 8 x 4 = 32, when 32 is subtracted from 35, we get 3 left over. This is 3 out of the next group of 8, so we have 3/8 of the next group.

c)
```
      408      8,573 ÷ 21 = 408 5/21
 21/8,573
    8 4
      173
      168
        5
```

"How many groups of 21 in 8,573?" 21 will not go into 8, so we try it into 85 (*Remember this is 8,500, really, so our first answer will go in the hundreds column). We find it goes 4 times, 4 x 21 = 84, subtracted from 85 leaves 1 (all in the hundreds column -- 21 x 400 = 8,400). Now we bring down the 7 from the tens column, and find we have 17 tens. This is not enough to make any groups of 21 tens, so we put a 0 in our answer to show that no groups of 21 tens were made. Next we bring down the 3 ones, and see how many groups of 21 ones we can make from 173 ones. We can make 8, we have 5 left, and these 5 are of our next group of 21 or 5/21.

<u>Practise in Division</u>

1. 8,690 ÷ 55 = ______

2. 2,592 ÷ 48 = ______

3. 67,640 ÷ 712 = ______

4. 3,686 ÷ n = 97   n = ______

5. 53,940 ÷ e = 620   e = ______

6. 5,056 ÷ n = 64   n = ______

17. FRACTIONS

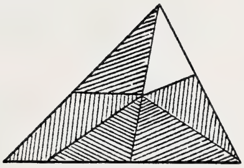
INTRODUCTION

Fractions (or rational numbers), usually refer to parts of a whole, or a whole and some parts. Numbers like 1/2, 3/5, 2 2/3, 7 3/5, 12/8, 14/3 are all types of fractions. In looking at a fraction, the bottom number (denominator) tells you how many pieces one whole thing was broken into. The top number (numerator), tells you how many of the pieces you have.

a)

Here, one rectangle was broken into 8 equal pieces. We get 3 of the pieces. This means we get 3 out of the 8 pieces, or 3/8 of the whole rectangle.

b)



Here, 1 whole triangle, broken into 6 pieces. Each piece is 1/6 of the triangle, we get 5 pieces, so we get 5/6 of the whole triangle.

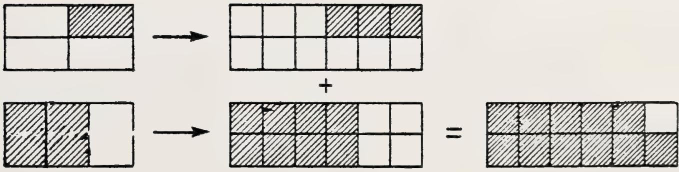
ADDITION OF FRACTIONS

In adding 2 or more fractions, if the bottom numbers are the same, that means the size of the pieces is the same and we can add easily.

a) $\begin{array}{r} 1/8 \\ +\ \underline{3/8} \\ 4/8 \end{array}$

Here, we see that 1/8 + 3/8 = 4/8, NOT 4/16. Each piece is 1/8 of the whole, and we have 3 of those eighths plus 1 of those eighths, so we get 4 of the eighths, or 4/8.

b) $\begin{array}{rcrcr} & 1/4 & \times\ 3/3 & = & 3/12 \\ + & \underline{2/3} & \times\ 4/4 & = & \underline{8/12} \\ & & & & 11/12 \end{array}$



Here we see that the piece sizes are different. We can do nothing until we get the bottom number to be the same. To do that, we must find a number that <u>both</u> bottom numbers will go into evenly. Here it is obviously 12. We change quarters and thirds to twelfths and we can work with them.

c)
```
3/4
2/4
---
5/4  = 1 1/4
```

If we have more pieces than we need to make a whole number, than we obviously go ahead and make the whole number! Here, 5 quarters is more than we need, because 4/4 is equal to one whole, so we get 1 whole, and 1/4 left.

d)
```
  3 1/8  =  3 1/8
+ 2 1/4  =  2 2/8
            -----
            5 3/8
```

Here we must add whole numbers and fractions, get the fractions to same size pieces, and get an answer (5 3/8).

e)
```
  4 3/4   =  4 9/12
+ 2 5/12  =  2 5/12
             ------
             6 14/12  =  7 2/12
```

Here we add, get a fractional part that is large enough to make another whole number, and end up with 7 2/12, or 7 1/6 in lowest terms.

$$\frac{2}{12} \div \frac{2}{2} = \frac{1}{6}$$

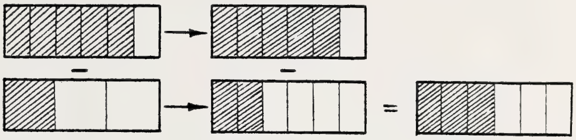
<u>Practise in Addition of Fractions</u>

1. 2/3 + 1/6 = ____________
2. 7/10 + 3/10 = ____________
3. 3/8 + 1/4 + 7/12 = ____
4. 3/5 + 1/2 = ____________
5. 3/16 + 5/8 = ____________
6. 1/12 + 5/12 = ____________
7. 16 1/2 + 5 1/2 = ____________
8. 23 2/3 + 12 5/6 = ____________
9. 9 3/4 + 2 1/5 = ____________
10. 5/9 + 15 7/12 = ____________
11. 13 5/8 + 7/8 = ____________
12. 4 9/10 + 6 1/15 = ____________

SUBTRACTION OF FRACTIONS

Basically, subtraction works as the opposite of addition. Again, we must get common denominators, or same size pieces, and then we subtract.

a) 5/6 = 5/6
- 1/3 = 2/6
3/6 = 1/2



Here we have an easy question. Notice how 1/2 was derived from 3/6? 3/6 is eqal to 1/2 as we can show:

b) 5 3/5 = 5 12/20
- 2 1/4 = 2 5/20
3 7/20

Here, another straight forward question.

c) 1 = 5/5
5 8/5
$\cancel{6}$ $\cancel{3}$/5
- 2 4/5

Not so straight forward! Looks easy, but... Here we must borrow. You cannot take 4/5 from 3/5, so we must get four fifths for the top number (not that kind of fifth!) We borrow one whole number, leaving 5 wholes. The one whole becomes 5/5 (because we are working with fifths, and need more at the top). Now the 3/5 + 5/5 becomes 8/5. 6 3/5 = 5 8/5 Right?

5 8/5
- 2 4/5
3 4/5

Question now reads 5 8/5 - 2 4/5, which then is a snap to do, and that is it for borrowing.

d) 5 1 = 8/8
$\cancel{6}$ 1/8 = 5 9/8
- 2 3/4 = 2 6/8
3 3/8

FIRST - get the fraction to common denominators, or same size pieces. Now we have to borrow so that we get enough eigths on top. Now, 5 9/8 - 2 6/8 is easy!

Practise in Subtraction of Fractions

1. 7/8 - 1/8 = __________

2. 4 1/2 - 3 5/6 = __________

3. 11 - 2 9/10 = __________

4. 15 7/12 - 5/8 = __________

5. 40 5/6 - 21 5/6 = __________

6. 20 3/4 - 19 15/16 = __________

7. 17 9/16 - 11 1/16 = __________

8. 4 3/10 - 5/6 = __________

MULTIPLICATION OF FRACTIONS

When multiplying by simple fractions, we are multiplying by less than one whole group. Therefore, we will get an answer of less than one group size. I'll try and show you:

6 x 3 = 18	3 groups of 6
6 x 2 = 12	2 groups of 6
6 x 1 = 6	1 group of 6
6 x 1/2 = ?	1/2 group of 6

You can see that the answer is 3, which is less than the group size, because we are only taking part of the group.

2/3 x 1/2 = n

This says take 1/2 a group of 2/3. This means our whole group, for this question, is just 2/3 of some amount. Now we want 1/2 of that group. We find we get 2/6 of the group.

$$2/3 \times 1/2 = 2/6 \text{ or } \frac{2 \times 1}{3 \times 2} = \frac{2}{6}$$

a) 5/8 x 3/4 = 15/32

Here, we multiply the numerators together to get 15 and the demonimators together to get 32. 3/4 of a group of 5/3 gives us 15/32 of a group.

b) 6 x 1/2 = n

6/1 x 1/2 = 6/2 = 3/1 = 3

Here, 1/2 a group of 6 is found to be 1/2 a group of 6 ones, which is 6/2 or 3 ones or 3 wholes.

c) 6 1/2 x 3 2/3

13/2 x 11/3 = 143/6 = 23 5/6

Here we have two mixed numbers being multiplied. We want 3 2/3 groups of 6 1/2. It is much easier to multiply fractions when we change them to improper fractions. This means that we look at 6 1/2 and say it is equal to 13/2 $\frac{(6 \times 2) + 1}{2}$ there being 2/2 in one whole, so 6 wholes has 12/2 + the 1/2 we had, making 13/2 and similarly for the 3 2/3. One should realize that our answer will be at least more than 18 wholes because 6 x 3 (the whole numbers in the question) will give us at least 18 wholes.

DO NOT DO IT <u>THIS</u> WAY:

6 1/2 x 3 2/3 = 18 + 2/6 = 18 2/6

It is 6 1/2 x 3 2/3, <u>not</u> (6 x 3) + (1/2 x 2/3)

<u>Practise in Multiplication of Fractions</u>

1. 5/8 x 2/3 = __________

2. 1/6 x 7/12 = __________

3. 3/5 x 1/2 = __________

4. 6/7 x 5/9 = __________

5. 5 2/3 x 9 = __________

6. 2 1/9 x 1 1/4 = __________

7. 4 1/8 x 3 3/5 = __________

8. 12 1/3 x 1 1/8 = __________

DIVISION OF FRACTIONS

When divididng by fractions, we are dividing by less than 1 whole group, and will get a larger number than we started with.

For example: 16 ÷ 16 = 1 There is 1 sixteen in 16

16 ÷ 8 = 2 There are 2 eights in 16

16 ÷ 4 = 4 There are 4 fours in 16

16 ÷ 2 = 8 There are 8 two in 16

16 ÷ 1 = 16 There are 16 ones in 16

16 ÷ 1/2 = n

n = 32 There are 32 halves in 16

*N.B. To do division of fraction questions, we invert the divisor, and multiply the new questions.

16/1 ÷ 1/2 = 16/1 x 2/1 = 32/1 = 32

a) 1/2 ÷ 2/3 = 1/2 x 3/2 = 3/4

1/2 is 2/3 of a group

3/4 is 3/3 of a group

Here is another question which asks "If 1/2 is 2/3 of a group, how much is 1 whole group?" We see that 1/2 is 2/3, 3/4 is 1 whole group, just as this question asks "If 8 is 4 groups, how much is one group?"

8 ÷ 4 = n

8/1 ÷ 4/1 = 8/1 x 1/4 = 8/4 = 2

We see that 8 is 4 groups, 2 is 1 group.

b) 3 1/2 ÷ 2/3 = n

7/2 ÷ 2/3 = 7/2 x 3/2 = 21/4

21/4 = 5 1/4

Here, 3 1/2 is 2/3 of the group. The whole group will obviously be more than 3 1/2. In fact it will be 1 1/2 times as large. Therefore, we multiply 3 1/2 x 1 1/2 or 3 1/2 x 3/2 and get our answer.

c) 6/7 ÷ 2

6/7 ÷ 2/1 = 6/7 x 1/2 = 6/14 = 3/7

Here, 6/7 is 2 groups, so 1 group will be 1/2 of 6/7, or 6/14 or 3/7.

d) 8 4/5 ÷ 3 1/6 = n

44/5 ÷ 19/6 = 44/5 x 6/19 = 264/95

Here 8 4/5 is equal to 3 1/6 groups. We need to find out how much in 1 group. We can expect our answer to be a bit more than 2, and find it be be 2 74/95.

<u>Practise in Division With Fractions</u>

1. 9/20 ÷ 1/2 = __________

2. 7/8 ÷ 7/12 = __________

3. 3/5 ÷ 3/10 = __________

4. 1/3 ÷ 9 = __________

5. 9 1/4 ÷ 6 = __________

6. 5 3/5 ÷ 4 = __________

7. 10 ÷ 3 1/3 = __________

8. 14 ÷ 7 3/4__________

9. 36 ÷ 1/4 = __________

10. 6 3/4 ÷ 1 1/3 = __________

11. 1/2 ÷ 6 2/3 = __________

12. 9 3/5 ÷ 1 1/5 = __________

18. DECIMALS

INTRODUCTION

This little chart is helpful in reading decimals and knowing which place we are talking about.

10x100	10x10	10x1/10	1/10	1/100	1/1000	1/10,000	1/100,000	1/1,000,000
1000	100	1	1	.01	.001	.0001	.00001	.000001
Getting larger pieces in each column to the left of the decimal point.			Getting smaller pieces in each column to the right of the decimal point.					

Decimals are similar to, and work the same as, regular fractions except all decimals are figured in fractions with denominator of 10 or multiples of ten (see chart) denominator -- bottom term of a fraction; size of piece.

If we have a regular fraction, and wish to make it into a decimal, we simply divide the number of pieces (numerator) by the size of the pieces (denominator); or, we make an equal fraction, with 10, 100, 1,000 or more as its denominator.

a) 1/2 = 5/10 = 0.5

(5 in the tenths column - first after the decimal reads as 5 tenths, or point 5).

b) $1/2 = 2\overset{\displaystyle .5}{\overline{)1.0}}$

Divide the numerator by the denominator, putting a decimal point after the numerator term. This always works, as 1/2 can be read as 1 divided into 2 parts. $1 \div 2 = 1/2 = 0.5$

c) 3/4 = 75/100 = 0.75 or

```
             .75
3/4 = 4/3.00
           2 8
             20
             20
              0
```

To change any fraction to a decimal fraction, divide the top term by the bottom term, put a decimal point after the top terms, and add as many zeros as required (Because 5 is is the same as 5.0 (five and 0 tenths), 5.00 - 5 and 0 hundredths, etc.).

d) 5/8 - 625/1000 = 0/625

```
             .625
5/8 = 8/5.000
           4.8
             20
             16
             40
             40
              0
```

e) 5 4/5 = 5 8/10

5 4/5 = 5 8/10 = 5.8

```
             .8
5  + 5/4.00 = 5.8
          4.0
            0
```

<u>Practise in Converting Fractions to Decimals</u>

1. 1/2 = __________ 4. 2 8/16 = 2.________

2. 7/8 = __________ 5. 34 6/8 = 34._______

3. 5/20 = _________ 6. 8 1/125 = 8._______

<u>ADDITION OF DECIMALS</u>

Addition of decimals is done in exactly the same manner as addition of whole numbers but there is ONE basic difference. The decimal point in the sums being added <u>must</u> stay in a vertical line, and be carried downward into the answer.

For example: $2.4 + 3.78 + 12.648 + 0.49 = n$

$n = 19.318$

$$\begin{array}{r} 2.4 \\ +\ 3.78 \\ +\ 12.648 \\ +\ \underline{0.49} \\ 19.318 \end{array}$$

In this example, the decimal point in each number says that the first digit to its right is tenths, the next is hundredths, etc. Therefore 2 and 4/10, plus 3 and 7/10 + 8/100, plus 12 and 6/10 + 4/100 + 8/1000, plus 4/10 + 9/100, must be kept in alignment as to tenths, hundredths, etc. If this is done, then similar units are added together by columns, and once the decimal is placed in the answer, we are done.

Practise in Addition With Decimals

1. 6.754 + 3.089 = __________

2. 0.3219 + 3.8476 = __________

3. Z - 3.48 = 2.97 Z = __________

4. 7.39 + 11.04 = __________

5. 6.4 + 8.27 + 19 = __________

6. 0.8 + 0.04 + 12 = __________

SUBTRACTION OF DECIMALS

Subtraction of decimals is handled the same as subtraction of whole numbers, once the decimal points are lined up.

For example:

$$\begin{array}{r} 4.86 \\ -\ \underline{2.43} \\ 2.43 \end{array}$$

Simply done when decimal points are aligned.

a) $6.04 - 2.843 = n$

$$\begin{array}{r} 6.04 \\ -\ \underline{2.843} \end{array} \qquad \begin{array}{r} 5\ \ 9\ 13\ 10 \\ \cancel{6}.\cancel{0}\cancel{4}0 \\ \underline{2.843} \\ 3.197 \end{array}$$

This can be done by remembering that to add zeros on <u>after</u> a decimal fraction does <u>not</u> change the value of the fraction

```
4/100  =  40/1000  =  400/10,000  etc
 0.04      0.040        0.0400    etc.
```

Once decimal points are aligned, be sure there are enough columns filled behind the decimal, then subtract as in whole numbers, putting the decimal point in the answer, vertically to the two in the question.

Practise in Subtraction With Decimals

1. 12.3 - 0.8 = __________

2. 17.34 - a = 12.63 a = __________

3. t + 0.6 = 7.1 t = __________

4. 14.238 - 10.255 = __________

5. 181.5 + z = 193.5 z = __________

6. w + 47.792 = 58.173 w = __________

7. 4.18 - 2.437 = __________

8. 16.4004 - 12.3 = __________

MULTIPLICATION OF DECIMALS

When multiplying decimals, it is best to ignore the decimal points completely, multiply as if they were whole numbers, then put as many decimal places in the answer as there were in both of the factors (factor times factor = product).

For example: 5.2 x 3.7

```
  5.2          THINK--  52    Then remember that there was
x 3.7                 x 37    one decimal point in each
 36 4                  364    factor, so we should have
156                   156     two decimal places in our
19.24                 1924    answer.
                       ↑
```

Here we have multiplied two numbers, both of which have tenths in their decimal fraction. Therefore, tenths times tenths (1/10 x 1/10) will give us hundredths (1/10 x 1/10 = 1/100) in our answer.

```
a)   4.07   2 decimal places
  x  2.4    1 decimal place
    1628
    814
   9.768    3 decimal places
```

Here we have tenths in the fraction part multiplied by hundredths in the other fraction part. Therefore, we get thousandths in the answer. (1/10 x 1/100 = 1/1000). (Remember the chart that began this section)'

b)

0.04	2 places
x 0.008	3 places
0.00032	5 places in answer

Here is a puzzler. We get an easy answer of 32, but 32 what? Well, our answer must be in hundred thousandths - 5 decimal places. We have 32 of these size pieces. Therefore, we must have 0.0032 as an answer. (4/100 x 8/1000 = 32/100,000 = 0.00032, NOT 0.32000. This says thirty-two thousand hundred thousandths, not just thirty-two hundred thousandths.

Practise in Multiplication With Decimals

1. 119.5 x 2 = __________

2. 7.3 x 0.96 = __________

3. 0.688 x 1.4 = __________

4. 2.3 x 8.7 = __________

5. 0.048 x 0.51 = __________

6. 12.66 x 48 = __________

7. 419 x 0.363 = __________

8. 76 x 29.4 = __________

9. 0.186 x 300 = __________

10. 0.278 x 69 = __________

DIVISION OF DECIMALS

This is one of the harder ideas to master, but really, it is quite simple. To put it plainly, dividing decimals is difficult, so we eliminate the decimal from the divider, and end up with no problems.

Let's backtrack. If 6 ÷ 2 = 3, what is 60 ÷ 20 going to equal? 3 of course. 600 ÷ 200? ...3! What about 24 ÷ 8 (6 x 4) ÷ (2 x 4), again, its 3!! So, we see that as long as we multiply the divisor and the dividend, both by the same number, our quotient remains the same.

$6 \div 3 = 2$

$60 \div 20 = 3$ divisor $\overline{)\text{dividend}}$ with quotient above

$18 \div 6 = 3$

$24 \div 8 = 3$ dividend $\div$ divisor = quotient

$600 \div 200 = 3$

Now, with that in mind, we can take care of any decimal division problems. We will simply eliminate decimals from the divisor.

For example: $48.16 \div 1.2 = n$ or $1.2\overline{)48.16}$

Well, the divisor has 1 decimal place, meaning it is really one and two tenths, or 1 2/10. To get rid of this fraction, we multiply the whole thing -- 1.2 and 48.16 by 10.

$$\begin{array}{r} 1.2 \\ \times\ \underline{10} \\ 12.0 \end{array} \qquad \begin{array}{r} 48.16 \\ \times\ \underline{\ \ 10} \\ 481.60 \end{array}$$

Now, we should be able to know that $48.16 \div 1.2$ will give us the same answer as $481.6 \div 12$ (remember $6 \div 2 = 3$, $60 \div 20 = 3$). So now we go ahead and divide as if all were whole numbers, then put the decimal in its vertical place in the answer.

```
   40.133
12/481.600
   48x xx
    01 6
     1 2
      40
      36
       40
       36
        4
```

At this point, we should realize again that we can hurt nothing by adding zeros on after a decimal fraction, so we may as well add on one or two more in the dividend.

Now, we see that the answer will repeat a 3 forever, so we call the total answer 40.13 1/3 or 40.133...

As we become familiar with these problems, we can get the divisor to a whole number quite quickly, as well as locate our new decimal point. All we must do is move the decimal point in the divisor <u>to the right</u>, until the whole divisor is a whole number. Then, to be sure and not change our answer, we must move the decimal in the dividend <u>an equal number of places to the right</u>. Now we proceed as above.

a) $4.27\overline{)8.8413}$ becomes $427\overline{)884.13}$
Here, divisor was multiplied by 100 (decimal point moved 2 to the right, as was dividend, and we are ready to go.

b) $6.831\overline{)247}$ becomes $6831\overline{)247000}$

Here, because we moved the divisor's decimal point 3 places to the right, we also had to move the dividend's decimal point 3 places to the right

<u>Practise in Division With Decimals</u>

1. $14.4 \div 6 =$ __________
2. $3 \div 0.25 =$ __________
3. $14.88 \div 6.2 =$ __________
4. $21 \div 24 =$ __________
5. $0.2 \div 0.04 =$ __________
6. $171.76 \div 45.2 =$ __________
7. $27.75 \div 375 =$ __________
8. $7.982 \div 0.26 =$ __________

19. ROUNDING OFF

Rounding off is simply a matter of eliminating a large group of digits, in favor of a close approximation to an actual number. For example, the population of Canada may be 21,847,643, but we say, for convenience, that the population is about 22,000,000, rounded to the nearest million.

a) 21,847,643 is 21,847,640 to the nearest ten

b) 21,847,643 is 21,847,600 to the nearest hundred

c) 21,847,643 is 21,848,000 to the nearest thousand

d) 21,847,643 is 21,850,000 to the nearest ten thousand

e) 21,847,643 is 21,800,000 to the nearest hundred thousand

f) 21,847,643 is 22,000,000 to the nearest million, and

g) 21,847,643 is 20,000,000 to the nearest ten million.

Rounding to a designated grouping is done by simply looking at the digit in the column to the right of the one we are rounding to. If that digit is 5 or less, we round the designated digit as is, or, in the case of example g) above, back to zero (because 21 million is closer to 20 million than 30 million - groups of ten million being needed).

This also applies in exactly the same way when rounding off decimal fractions to their designated places; i.e., 6.04982, rounded to the nearest hundredth is, 6.05, the 9 in the column to the right of the designated column is larger than 5, so we round the designated column up by 1.

20. RATIO AND PERCENTAGE

RATIO

Ratios have the appearance of fractions if written as 1/2. This can mean 1 or 2 or 1 per 2. Ratios can also be written as 1:2.

When using ratios, we always are comparing two things. If we have 4 apple trees and 6 peach trees, the ratio is 4:6. If we say we have 6 peach trees to 4 apple trees, the ratio is 6:4. The first item mentioned in comparison is generally the first item shown in the ratio.

Ratios may be quite useful as new equipment is purchased. Suppose you use 6 gallons of some chemical in combination with the contents of a 90 gallon tank. You receive a new tank holding 150 gallons. How much chemical should be added?

$$\frac{\text{chemical}}{\text{tank}} = \frac{6}{90} = \frac{n}{150}$$

We know that a) $1/2 = 3/6$; $a/b = c/d$

$a \times d = b \times c$

b) $3/4 = 6/8$

Therefore we can see that in a) $1 \times 6 = 3 \times 2$: and in b) $3 \times 8 = 6 \times 4$. In our question then, we see that $6 \times 150 = 90 \times n$. We know that $900 = 90 \times n$ which can be solved by divisor

$$90\overline{)900}^{\;10}$$

We need 10 gallons of chemical for the new tank.

$6/90 = 10/150$ -- These are equal ratios, as we proved.

Practise in Using Ratios

1. $\frac{15}{45} = \frac{X}{3}$ X = __________

2. $\frac{b}{25} = \frac{100}{50}$ b = __________

3. $\frac{32.3}{1} = \frac{f}{43}$ f = __________

4. $\frac{2.3}{1.2} = \frac{V}{2.4}$ V = __________

5. $\frac{6.24}{z} = \frac{14}{28}$ z = __________

6. $\frac{14}{100} = \frac{a}{65}$ a = __________

7. $\frac{43.1}{16} = \frac{431}{n}$ n = __________

8. $\frac{14}{56} = \frac{c}{40}$ c = __________

9. $\frac{42.35}{1} = \frac{d}{4.2}$ d = __________

10. $\frac{100}{73} = \frac{5}{2}$ w = __________

PERCENTAGE

Per cent is a special ratio, which is always a ratio "out of a 100". (Remember 100 cents in a dollar -- per cent -- per 100 -- out of 100).

$$12/50 = n/100$$

$$12 \times 100 = 50 \times n$$

$$1200 = 50 \times n$$

$$\frac{1200}{50} = n$$

$$24 = n$$

Here, 12 units out of 50 is found to be 24% (24/100)

As per cent is really expressed as a fraction with denominator 100, the above example could be said to read 0.24 but NOT 0.24%. Once the % sign goes with the number, then the number is considered as being out of 100, 0.24% means 0.24/100, which is roughly 1/4 of 1 percent, not the 24% we intended it to be.

We can also find per cent without working from two fraction-like operations. We can divide the part by the total, get a two place decimal answer (at least), and develop a per cent from there.

For example: Let's suppose you had a 440 gallon tank that needed to be 11% treated with some chemical. You think it should take 48.4 gallons of chemical, but you aren't sure. Let's figure the percentage of chemical that 48.4 gallons is, of the 440 gallon tank.

a) $\frac{\text{chemical}}{\text{tank}} \quad \frac{48.4}{440} = \frac{n}{100}$

$$\begin{array}{r} 11 \\ 440\overline{)4840} \\ \underline{440} \\ 440 \\ \underline{440} \\ 0 \end{array} \quad n = 11\%$$

b)

$$\begin{array}{r} .11 \\ 440\overline{)48.40} \\ \underline{44\ 0} \\ 4\ 40 \\ \underline{4\ 40} \\ 0 \end{array}$$

$n = 11\%$

a) Answer: yes, 48.4 gallons is 11% of 440 gallons

b) Answer: yes, 48.8 gallons is .11 of 440 gallons.

Both answere are right, because 11% is 11 out of 100, or .11! When per cent is used regularly, method b) becomes easier, as it is much faster.

Practise in Using Percentages

1. 42 is 84% of __________
2. 65% of 20 is __________
3. 100 is __________% of 25
4. 36 is 180% of __________
5. 14 is __________% of 200
6. 210% of 100 is __________
7. 92 is __________% of 50
8. 38% of 300 is __________

21. REVIEW EXERCISES

REVIEW EXERCISES IN ADDITION

1. 96,822 + 4,879 = __________

2. 87,001 + 999 = __________

3. N - 6,476 = 1,548 N = __________

4. t - 95,865 = 796 t = __________

5. s - 8,373 = 812 s = __________

REVIEW EXERCISES IN SUBTRACTION

1. 41,731 - 39,845 = __________

2. 5,340 + w = 18,342 w = __________

3. 70,507 + y = 76,299 y = __________

4. 7,403 - t = 114 t = __________

REVIEW EXERCISES IN DIVISION

Round all answers to the nearest hundredth (i.e., 7.0489 becomes 7.05)

1. 250,610 ÷ 724 = __________

2. 50,742 ÷ 683 = __________

3. 83,927 ÷ 89 = __________

4. 17,591 ÷ 49 = __________

5. 71,906 ÷ 187 = __________

6. 16,074 ÷ a = 19 a = __________

7. 5,656 ÷ w = 119 w = __________

8. 294,850 ÷ h = 724 h = __________

9. 42,293 ÷ d = 83 d = __________

10. 74,746 ÷ r = 983 r = __________

REVIEW EXERCISES IN ADDITION USING DECIMALS

1. 6.2 + 7.5 = __________

2. 72.04 + 16.93 = __________

3. 0.0037 + 25.4292 = __________

4. 3.682 + 7.425 + 8.399 = __________

5. 17.93 + 0.02 + 0.64 + 1.77 = __________

6. 37.1 + 19.8 + 2.6 + 107.3 = __________

7. 0.1894 + 0.3625 + 0.1818 = __________

8. 37.56 + 7.39 + 9.28 = __________

9. 0.745 + 0.631 + 0.892 = __________

10. 7.2 + 0.6 + 4.5 + 0.9 = __________

11. 19.52 + 17.48 + 3.12 = __________

12. z - 72.831 = 2.695 z = __________

13. f - 1.076 = 21.434 f = __________

14. a - 3.345 = 9.728 a = __________

15. b - 6.72 = 3.49 b = __________

REVIEW EXERCISES IN SUBTRACTION USING DECIMALS

1. 4611.5 - 3898.7 = __________

2. 1.249 - 0.985 = __________

3. 3.227 - 1.895 = __________

4. 7.39 - 0.78 = __________

5. 0.793 - 0.55 = __________

6. 21.3 - 6.7 = __________

7. 3.7748 - 3.2798 = __________

8. 51.16 - 14.02 = __________

9. 8.5363 - 4.5607 = __________

10. 1.784 - 0.939 = __________

11. 18.76 - 3.49 = __________

12. 125.3 - 124.8 = __________

13. r + 695.40 = 710.01   r = __________

14. 178.36 + d = 200.05   d = __________

15. 8492 - b = 183.9   b = __________

16. 6936.1 + g = 9023.5   g = __________

17. 735.729 - 30.015 = __________

18. 36.46 - z = 18.95   z = __________

19. w + 0.3596 = 6.0085   w = __________

20. 6.38 + m = 17.92   m = __________

REVIEW EXERCISES USING PERCENTAGES

1. 75% Of 48 is ______
2. 305.28 is ____% of 318
3. 9.7 is 16% of _____
4. 2.16 is _____% of 72
5. 147% of 147 is _____
6. 49 is 50% of _____
7. 1.21 is ____% of 11
8. 38 is 250% of _____
9. 1 % of 300 is _____
10. 32.4 is 6% of _____
11. 138.32 is ____% of 76
12. 25% of 69 is ____
13. 14% of 244 is _____
14. 75 is 150% of _____
15. 8.41 is _____% of 29
16. 88 is 88% of _____
17. 7.2 is _____% of 16
18. 63% of 42 is _____
19. 77 is 16% of _____
20. 18.4% of 182 is _____

22. UNITS OF MEASUREMENT

LINEAR

1 inch (in.) = 2.54 centimetres (cm)

1 foot (ft.) = 12 inches = 30.48 cm

1 metre (m) = 39.37 inches = 3.28 feet = 1.094 yd.

AREA

1 square foot (sq. ft. or ft^2) = 144 square inches (sq. in. or in^2)

1 acre (Ac) = 43560 sq. ft.

1 square mile = 640 Ac

VOLUME AND CAPACITY

1 cubic inch (cu. in. or in^3)

1 cubic foot (cu. ft. or ft^3) = 1728 cu. in. = 7.5 U.S. gallons

= 6.23 Imperial gallons

1 gallon (gal.) = 4 quarts (qt.) = 8 pints (pt.)

1 litre (L) = 1000 millilitres (mL) = 1.057 qu. (U.S.)

= 0.88 Imperial quarts

= 100 cubic centimetres (cc)

π = 3.1415 or 22/7

WEIGHT

1 ounce = 28.35 grams

1 pound (lb. or #) = 16 ounces (oz.) = 453 grams (gm) = 7000 grains (gr.)

1 kilogram (kg) = 1000 grams = 2.205 pounds

1 cubic foot of water weighs approximately 62.4 pounds

1 U.S. gallon water weighs approximately 8.33 pounds

1 Imperial gallon of water weighs approximately 10.0 pounds

1 litre of water weighs approximately 1 kilogram or 1000 grams

1 millilitre of water weighs approximately 1 gram

1 foot of water = 0.43 pounds per square inch

1 pound per square inch = 2.31 feet of water

CONCENTRATIONS

1 part per million (ppm) = 1 milligram per litre (mg/L)
= 0.058 grains per gallon (gpg)

1 grain per Imperial gallon = 14.25 ppm

1 grain per U.S. gallon = 17.1 ppm
= 143 pounds per million gallons (lb/MG)

PRACTISE IN USING UNITS OF MEASUREMENT

Round all answers to the nearest hundredth (i.e., 7.0489 becomes 7.05).

1. 16 sq. ft. = ____________ sq. in.

2. 9 cu. ft. = ____________ cu. in.

3. 1584 sq. in. = __________ sq. ft.

4. 5184 cu. in. = __________ cu. ft.

5. 45 sq. ft. = ____________ sq. in.

6. 2880 sq. in. = ___________ sq. ft.

7. 172,800 cu. in. = _________ cu. ft.

8. 12 sq. ft. = ____________ sq. in.

9. 19 cu. ft. = ____________ cu. in.

10. 6 sq. ft. = ______________ sq. in.

11. 200 cm = ________________ m

12. 11 m = __________________ cm

13. 30,500 sq. cm = __________ sq. m

14. 2.2 sq. m = __________ sq. cm

15. 550,000 cc = __________ cu. m

16. 0.8 cu. m = __________ cc

17. 3 in. = __________ cm

18. 26 cm = __________ inches

19. 3 ft. = __________ cm

20. 70 cm = __________ ft.

21. 3 m = __________ ft.

22. 8 ft. = __________ m

23. 11 cu. ft. = __________ Imp. Gal.

24. 17 l = ______________Imp. qt.

25. 33 Imp. qt. = __________ l

26. 7 lbs. = __________ gm

27. 906 gm = __________ lb.

28. 5 kg = __________ lbs.

29. 7 lbs. = __________ kg

30. 1200 gm = __________ lbs.

23. PROBLEM SOLVING

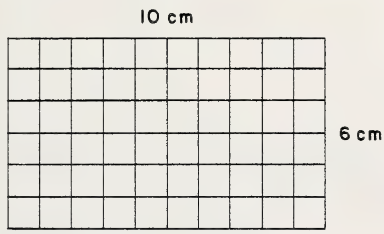
INTRODUCTION

The first thing you must be able to do in solving work problems with mathematics is to read the question to see what is asked! Then by fitting the problem to one of the eight fundamental forms (page 77) we try to solve it. If it is a percentage, or area question, we can solve it by using the previously learned formulas. Some problems will be easily solved, others are more difficult. Remember -- read to see what is wanted.

AREA

Area refers to the number of square units required to cover a surface.

For example:



If this is our area, we will want to know how many squares each 1 cm by 1 cm it will take to cover this. We can see it takes 60 centimetre squares.

Area of a rectangle = length x width

$$A = l \times w$$

$$A = 10 \text{ cm} \times 6 \text{ cm} = 60 \text{ cm}^2$$

Areas of triangles, parallelograms, trapezoids, and circles are also found in square units, and the formulas listed elsewhere are used for the numerical values.

Practise Problems Using Areas

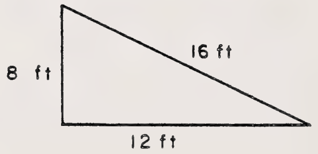
1. If Mr. Jones has a rumpus room 17 feet by 12 feet, and wishes to carpet the area, how much carpet will he need? How much will it cost if the carpet is $7.50 per square foot? $11.95 per square yard? Remember -- 1 sq. yd. = 9 sq. ft.

2. A new parking garage is being built. It will have six floors, each 200' by 80'. If each car to be parked required 80 sq. ft. of space, (eliminating driveway areas), how many cars can be parked on the six levels? On one level?

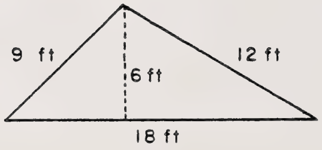
3. A flower garden is 16 feet x 20 1/2 feet. What is its area in sq. ft? sq. yds?

4. Mr. Brown bought lawn seed for his yard. He planned to use 1 lb/220 sq. ft. of yard. If his yard was 55' by 60', how much grass seed does he need?

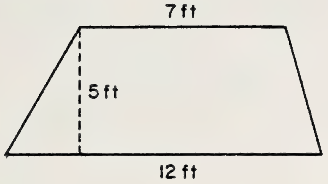
5. Area = __________ sq. ft.



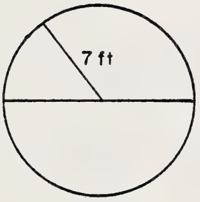
6. Area = __________ sq. ft.



7. Area = __________ sq. ft.



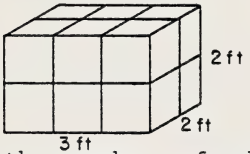
8. Area = __________ sq. ft.



VOLUME

The volume of an object refers to the amount which can be put into or contained by an object; i.e., how much water can be put in an aquarium, a swimming pool, or a storage tank. Several formulas are used in this computation as well.

For example:



Volume -- the number of cubic units required to fill something. Here we see we need 12 cubes, each 1 ft. x 1 ft. x 1 ft. to build this shape (or fill it if it is empty).

Volume of a Rectangular Solid

V = l x w x h

= length x width x height

= 3 ft. x 2 ft. x 2 ft. = 12 cubic feet

Volume is always referred to by cubic units: cu. ft. cm^3, m^3, cc.

Volumes of spheres, cylinders, cones, and pyramids can be determined by formulas found elsewhere. Always express volumes in cubic units.

Practise Problems Using Volume

1. Jones wants to build a swimming pool. He digs a hole 6 ft. deep and 20 ft. square. How much water will he need to fill it, in cubic feet? In gallons? (1 cu. ft. of water = 6.23 gallons).

2. To catch rainwater for her favorite facial, Maggie bought a large tank, cylindrical in shape. Soon, runoff filled the tank with precious rainwater. If the tank had a diameter of 8 feet, and a height of 6 feet, would there be enough water there (assume no more rain) to provide Maggie with 1 cu. ft. of water per day for July and August? How much water would there be left over, or would there be short?

3. The volume of a rectangular aquarium 20 in. x 10 in. x 12 in. would be __________?

4. An open holding tank 40 ft. x 50 ft. x 12 ft. would contain:

   i) How many cubic feet of water?
   ii) How many gallons ?
   iii) What would the weight of water in the tank be?
   iv) What would the area of the tank's interior surfaces be?
   v) If 1 gallon of paint covers 800 square feet, how much paint would be needed to provide 2 coats to the interior of the tank?

PERCENTAGE

Percentage problems usually ask one of three things:

i) find a percentage;

ii) given a percentage, find the part of the whole; or
iii) given a percentage, find the total using a part.

For example:

i) 12 out of 30 people wear glasses. What percent is this?

$$\frac{12}{30} = \frac{n}{100} = 12 \times 100 = 30 \times n = \frac{1200}{30} = n$$

$n = 40\%$

ii) 60% of the people own cars and there are 250 people altogether. How many people own cars?

$$\frac{n}{250} = \frac{60}{100} = 60 \times 250 = 100 \times n$$

$$= \frac{15000}{100} = n$$

$n = 150$

Out of the whole group, 150 people own cars.

iii) 40% of the people in a group have red hair. 8 of the people in the group have red hair. How many people are there in the total group?

$$\frac{8}{n} = \frac{40}{100} = 8 \times 100 = 40 \times n$$

$$= \frac{800}{40} = n$$

$n = 20$

There are 20 people in the whole group.

Practise Problems Using Percentage

1. Jones bought a radio on sale for $45. That price was 60% of the regular price. What was the regular price?

2. 1% of an aquarium is to be chlorine. The aquarium holds 2400 litres of water. How much chlorine should be added?

3. 22 kg of rock salt was bought to be used in water as a 4% solution. How many litres of water would this amount of rock salt be able to treat?

4. John missed 6% of his yearly work total due to illness. If he normally works 300 days per year, how many days did he miss?

5. Sue earns a taxable income of $14,440.00 per year. Her tax rate is 28% on the first $8,000, 30% on the next $5,000, and 32% on the next $5,000 or part thereof. How much is she left with after paying her tax?

RATES

A rate is a number multiplied by a physical unit. This physical unit is formed by dividing one physical unit by another and is called the rate unit.

For example: A channel delivers in steady flow 4,400 cubic feet ($ft.^3$) in four hours.

$$\frac{4400\ ft.^3}{4\ hours} = \frac{4400}{4}\ \frac{(ft.)}{(hours)} = 1{,}100\ ft.^3 \text{ per hour}$$

To calculate desired units not given, two rules are used:

1. Physical units may be cancelled

2. Any quantity divided by its equivalent equals unity.

For example? How many centimetres in 1 foot?

Simply multiply the number of centimetres in one inch by the number of inches in one foot.

$$\frac{2.54 \text{ cm}}{1 \text{ inch}} \times \frac{12 \text{ inches}}{1 \text{ foot}} = 30.48 \text{ centimetres per foot.}$$

For example: What quantity of water weights one pound? Give your answer in Imperial gallons.

$$\frac{10 \text{ lbs}}{1 \text{ gal.}} = \frac{1 \text{ lb}}{X \text{ gal.}} =$$

$$X = \frac{1 \text{ lb} \times 1 \text{ gal.}}{10 \text{ lbs.}}$$

$$X = \frac{1}{10} = 0.1 \text{ gallons}$$

Converting One Set of Units to Another

Problem: One ounce per gallon is equal to:

a) How many pounds per cubic feet?

b) How many grams per litre?

a) $$\frac{1 \text{ ounce}}{1 \text{ gallon}} = \frac{1 \text{ ounce}}{1 \text{ gallon}} \times \frac{6.24 \text{ gallons}}{1 \text{ cu. ft.}} \times \frac{1 \text{ pound}}{16 \text{ ounces}}$$

$$= \frac{6.24 \text{ pounds}}{16 \text{ cu. ft.}} = \frac{0.39 \text{ pounds}}{\text{cu. ft.}}$$

b) $$\frac{1 \text{ ounce}}{1 \text{ gallon}} = \frac{1 \text{ ounce}}{1 \text{ gallon}} \times \frac{1 \text{ gallon}}{4.54 \text{ litres}} \times \frac{28.35 \text{ grams}}{1 \text{ ounce}}$$

Density and Specific Gravity

The density of any object is the ratio of its mass to its volume. The mass is taken as equal to its weight.

$$D = \frac{W}{V}$$

The numerical value of the density depends on the units of weight and volume. There are three sets of units in common use. They are:

Grams per millitre

pounds per cubic foot

pounds per gallon

It is therefore necessary that the units accompany the numerical value.

Substance	Pounds/ft.^{3}
Air	0.795
Cork	15.0
Ice	57.5
Iron, wrought	480.0
Water, $0^{\circ}C$	62.417

Problem: Calculate the weight of wrought iron bar that is 13 feet x 4 inches x 4 inches.

$$\text{Volume (ft.}^3\text{)} = 13 \times \frac{4}{12} \times \frac{4}{12} = 1.44 \text{ (ft.)}$$

$$\text{Weight} = 1.44 \text{ cu. ft.} \times \frac{480 \text{ lbs}}{\text{ft}^3} = 691.2 \text{ pounds}$$

Specific Gravity

Specific gravity and density are closely related. Specific gravity is a relative density. It is obtained by dividing the density of the object by the density of some reference substance. Water is the usual reference substance. It is often thought of as the weight of an object divided by the weight of an equal volume of water. For exact specifications the temperature of the object and the water must be given.

24. REVIEW PROBLEMS

1. A man earned $267.75 for 42.5 hours of work. How much was he paid per hour?

2. A piece of land 484 feet wide was marked off into lots. Each lot was 60.5 feet wide. How many lots were in the piece of land?

3. The area of Yoho and Kootenay National Parks together is 25% of the area of Jasper National Park. Yoho and Kootenay cover 1050 square miles. What is the area of Jasper?

4. On Highway 28, the distance from Hometown to High Falls is 12 3/4 miles farther than it is on Highway 11. The distance on Highway 11 is 36 1/2 miles. What is the distance on Highway 28?

5. Mr. May bought 75 feet of garden hose that was priced at $6.30 for 50 feet. At this rate, how much did he have to pay for the 75 feet of hose?

6. Mr. Downs bought 3 rolls of black and while film at a total cost of $3.15. He also bought 3 rolls of color film at a cost of $2.75 per roll. He paid how much more for the 3 rolls of color film than for the 3 rolls of black and white film?

7. 35% of the people who work in Mr. Miller's office drive their cars to work. 120 persons work in Mr. Miller's office. How many of these people drive their cars to work?

8. Mrs. Jackson paid $2.25 for a 3 lb. roast of beef at the Beach Store. Mrs. Phillips paid $2.04 for a 3 lb. roast of beef at the Sanderson Store. The price of roast beef per pound was how much more at the Beach Store than at the Sanderson Store.

25. SAMPLE PROBLEMS RELATING TO WATER AND WASTEWATER TREATMENT

Problem 1.

A settling tank is 40 feet long by 15 feet wide by 10 feet deep.

a) What is the surface area in square feet?

b) What is the volume in cubic feet?

c) What is the volume in Imperial gallons?

Solution

a) Surface area of tank in square feet.

$$A = 40 \times 15 = 600 \text{ square feet}$$

b) Volume of tank in cubic feet

$$V = \text{length} \times \text{width} \times \text{depth}$$

$$V = 40 \times 15 \times 10 = 6000 \text{ cubic feet } (\text{ft.}^3)$$

c) Volume in Imperial gallons

$$1 \text{ ft}^3 = 6.24 \text{ Imperial gallons}$$

$$6000 \text{ ft}^3 = 6.24 \times 6000 \text{ Imperial gallons}$$

$$V = 37{,}440 \text{ Imperial gallons}$$

Problem 2.

An elevated tank has a diameter of 20 feet. The bottom is a semi sphere and the vertical height of the side is 25 feet. One gallon of protective coating covers 100 square feet.

a. How many square feet are in the sides and bottom of the tank?

b. How many gallons of protective coating are required to cover this area?

c. How much water will the tank hold?

d. The top of the water in the tank is 100 feet above a pressure gauge. What does the pressure gauge read (p.s.i.)?

Solution

a. Number of square feet on the inside surface of the walls and bottom of the tank are:

Walls of cylinder 25 feet tall (L) and having a radius of 10 feet (r)

Lateral area = $2\pi rL$

$$= 2 \times \frac{22}{7} \times 10 \times 25$$

$$= 500 \times \frac{22}{7}$$

$$= \frac{11000}{7} \quad - 1571 \text{ square feet}$$

Bottom area is half a sphere

$$A = \frac{1}{2} \times 4\pi r^2$$

$$= \frac{1}{2} \times 4 \times \frac{22}{7} \times 10 \times 10 = \frac{4400}{7} = 628.5$$

say 629 square feet ($ft.^2$)

Total area of sides and bottom is 1571 + 629 = 2200 $feet^2$

b. Number of gallons of protective paint required are

1 gal. does 100 sq. ft.

$$\text{gals. required} = \frac{2200}{100} = \underline{22}$$

c. Number of gallons the tank will hold

Volume of cylinder = $\pi r^2 L$

$$V = \frac{22}{7} \times 10 \times 10 \times 25$$

$$\underline{V. = 7850 \text{ ft.}^3}$$

Volume of 1/2 spherical bottom

$$V = 1/2 \times 4/3\pi r^3$$

$$V = 1/2 \times 4/3 \times \frac{22}{7} \times 10 \times 10 \times 10$$

$$V = 1/2 \times 4/3 \times \frac{22}{7} \times 1000$$

$$= \frac{44}{21} \times 1000 = \frac{44000}{21}$$

$\underline{\text{Volume of bottom} = 2094 \text{ ft.}^3}$

Total volume of tank = 7850 + 2094 ft.^{3}

= 9944 ft.^{3}

Volume in Imperial gallons = 6.24 x 9944

$\underline{V = 62{,}000 \text{ gallons}}$

d. How many pounds per square inch is exerted by a column of water 100 feet high?

1 ft.^{3} water weights 62.4 pounds

There are 144 sq. inches in one sq. foot

Each square inch supports $\frac{62.4}{144}$ = 0.433 lbs.

100 feet of water will therefore exert 100 x 0.433

= 43.3 lbs/in.^{2}

<u>Problem 3</u>.

Suppose a plant uses 35 pounds of alum per day, how long will two tons of alum last?

<u>Solution</u>

Two tons (4000 lbs.) of alum is used at the rate of 35 lbs/day will last

$$\frac{4000 \text{ lbs.}}{35 \text{ lbs.}} \quad \underline{\text{day}} = 114.2 \text{ days}$$

Problem 4.

A sludge drying bed has two parallel sides, one of which is 20 feet in length, the other 40 feet. The perpendicular distance between these two sides is 15 feet.

a. What is the area of the drying bed?

b. If there is six inches of sludge on the bed, what volume does this represent (cubic feet)?

c. If 1/2 square feet is necessary for one person, how many people will this drying bed facilitate?

Solutions

a. Area of the drying bed (use formula for area of trapezoid)

$$A = 1/2\ (b + c)\ a$$

$$A = 1/2\ (40 + 20)\ 15$$

$$A = 1/2 \times 60 \times 15 = 450\ \text{ft.}^2$$

b. Volume of sludge 6 inches deep

$$V = \text{area} \times \text{depth}$$

$$V = 450 \times 1/2$$

$$V = 225\ \text{ft.}^3$$

c. At 1 1/2 sq. feet per person the drying bed will serve

$$\frac{450}{1\ 1/2} = \frac{450}{3/2} = 450 \times 2/3 = \underline{300\ \text{people}}$$

Problem 5.

A circular reservoir 50 feet in diameter stores filtered water. To check the rate of filtering, the rise in the water surface is checked and found to be one foot per hour, when the outlet is closed.

a. What is the rate of flow through the filters in cubic feet per hour?

b. Rate in gallons per minute? (imperial)

c. Rate in million Imperial gallons per day (M.G.D., Imperial)?

Solution

a. The volume of water coming from the filters to the reservoir in one hour is the volume contained in a cylinder 50 feet in diameter and 1 foot high.

$$V = \pi r^2 L$$

$$= 3.14 \times (25)^2 \times 1 \text{ cubic foot}$$

$$= 1960 \text{ ft.}^3$$

b. The rate in gallons per minute is

$$1960 \frac{\text{ft.}^3}{\text{hr.}} \times 6.24 \frac{\text{gal}}{\text{ft.}^3} \times \frac{\text{hr.}}{60 \text{ min.}} = 204 \text{ gpm}$$

c. The rate in million gallons (Imp) per day is

$$204 \frac{\text{gal.}}{\text{min.}} \times 1440 \frac{\text{min.}}{\text{day}} \times \frac{\text{M.G.}}{1{,}000{,}000 \text{ gal.}} = 0.294 \text{ MG./D.}$$

Problem 6.

A venturi meter indicates that the velocity in an eight inch pipe is four feet per second. What is the rate of flow in Imperial gallons per minute.

Solution

First we must determine the volume of water in 4 feet of 8 inch pipe.

Pipe Area - πr^2

$$= 3.14 \times (4)^2 \frac{\text{inches squared}}{144} \times \frac{\text{ft.}^2}{\text{square inches}}$$

$$= .349 \text{ ft.}^2$$

Volume in 4 feet of pipe = $.349 \text{ ft.}^2 \times 4 \text{ ft.} = 1.396 \text{ ft.}^3$

This volume flows in 1 second. Now what will be the rate in Imperial gpm?

$$\frac{1.396 \text{ ft.}^3}{1 \text{ second}} \times \frac{6.24 \text{ gal.}}{\text{ft.}^3} \times \frac{60 \text{ sec.}}{\text{min.}} = 522 \text{ Imperial gpm.}$$

Problem 7.

The specific gravity of slaked lime is .70. The lime is in bags which are to be stacked in a store room. The allowable load is 800 pounds per square foot. Contact area of each bag is 2.8 square feet.

How high can the bags be stacked?

Solution

Specific gravity of .7 means that the weight of lime is .7 times the weight of water or 0.7 x 62.4 $lbs./ft.^3$ = 43.7 $lbs/ft.^3$/ We are allowed to load the floor at 800 $lbs/ft.^2$.

The height we may go in stacking them therefore is:

$$800 \frac{\text{lbs.}}{\text{ft.}^2} \times \frac{1 \text{ ft.}^3}{43.7 \text{ lbs.}} = 18.3 \text{ ft.}$$

Problem 8.

Calcium Hypochlorite (HTH) has 70% available chlorine. How many pounds of HTH are required to make a solution of 5% chlorine in a 20 gallon (Imperial) crock?

Solution

A 5% solution means 5 lbs. of chlorine to 100 lbs. of water. We have 20 Imperial gallons of water or 20 x 10 = 200 lbs. of water. For every 100 lbs. we need 5 lbs. of chlorine. We therefore need 5/100 x 200 = 10 lbs. of chlorine. Since HTH is only 70% effective (.7) we will require more pounds of HTH powder than 10 pounds. We actually require $\frac{10}{.7}$ = 14.3 lbs.

Problem 9.

Calcium hypochlorite contains 70% available chlorine by weight. How many pounds per day would be required to give a dosage of two parts per million in a flow of 35 Imperial gallons per minute?

Solution

We are asked to add chlorine to a stream of water at a rate of two parts per million

Since one part per million means one pound in one million pounds, then two parts per million of chlorine in water means two pounds of chlorine in one million pounds of water.

The next step is to determine how much water is to be treated in one day. The flow rate is 35 Imp. gpm and from the table of conversion

factors we know that 1 mgd (million gallon per day) = 700 gpm (gallons per minute)

Since 700 gpm = 1.0 mgd

Then 35 gpm $= 1.0 \times \frac{35}{700} = 0.05$ mgd

And 0.05 mgd = 50,000 gallons/day

Now we must find the weight of water to be treated in one day.

1 gallon Imperial = 10 lbs. of water

Therefore 50,000 Imp. gal. = 50,000 x 10

= 500,000 lbs. of water

As we found earlier, we need two pounds of chlorine for every million pounds of water.

1,000,000 lbs. of water requires 2 lbs of chlorine

Therefore 500,000 lbs of water needs $2 \times \frac{500,000}{1,000,000} = 1.0$ lb. of chlorine

We must remember that all the chlorine powder we added did not contain chlorine; only 70% of it did. We must therefore add more than 1.0 lb. of powder.

Now, 0.7 lbs. of chlorine = 1.0 lbs. of calcium hypochlorite

Therefore, 1.0 lb. of chlorine $= 1.0 \times \frac{1.0}{0.7}$

= 1.43 lbs. of calcium hypochlorite

Therefore, we require 1.43 lbs. of calcium hypochlorite to provide the required dosage.

Answer - 1.43 lbs./day

Problem 10.

How many pounds of alum would have to be dissolved in 60 Imperial gallons of water to give a 5 percent solution?

Solution

First of all, we must consider what is meant by a 5% solution. Very simply, 5% means 5/100. Therefore, a 5% solution of alum means 5 lbs. of alum in 100 lbs. of water.

In this problem we are asked to find how much alum is required to make a 5% solution in 60 Imp. gallons of water. It will therefore be necessary to change 60 Imp. gallons to pounds.

1 Imp. gallon = 10 pounds of water

60 Imp. gallons = 60 x 10

= 600 pounds of water

In order to make the 5% solution we know that

100 lbs. of water uses 5 lbs. of alum

Therefore, 600 lbs. of water uses $5 \times \frac{600}{100} = 30$ lbs. of alum

We therefore require 30 pounds of alum for 60 Imp. gallons of water to make a 5% solution.

Answer - 30 pounds

Problem 11.

The rate of fall of water on a filter is 3 inches per minute. What is the filter loading in U.S. gallons per minute per square foot? (Note: The standard filter loading is 2 U.S. gpm per square foot.)

Solution

If we consider only one square foot of this filter for ease of calculations, we know that a volume one square foot in area by 3 inches deep passes through the filter each minute. It is therefore a question of converting that volume to gallons.

We know that 3 inches is 1/4 of a foot. Therefore, the volume in cubic feet passing through the filter in one minute is:

1' x 1' x 1/4' = 1/4 cubic foot.

From the table we know that

1 cubic foot = 7.5 U.S. gallons

Therefore, 1/4 cubic foot = 7.5 x 1/4

= 1.875 U.S. gallons

The rate of fall is therefore 1.875 U.S. gpm/sq. foot.

Answer - 1.875 U.S. gpm/sq. ft.

Problem 12.

What is the detention period in hours in a primary settling tank that is 40' long by 10' deep by 10' wide and where the flow is 700,000 Imperial gallons in 24 hours?

Solution

Whenever you are asked what the detention time is in any basin, what really is being asked is - How long does it take to fill that tank at the flow rate indicated?

The first step in solving our problem is to find the volume of our tank, which is 40' long by 10' deep by 10' wide.

Volume = length x depth x width

= 40' x 10' x 10'

= 4,000 cubic feet

The next step is to convert the volume into gallons

1 cubic foot = 6.24 Imp. gallons

Therefore 4,000 cubic feet = 6.24 x 4,000

= 24,960 Imp. gallons

Now we must consider the flow rate of 700,000 Imp. gallons in 24 hours.

Flow rate = 700,000 Imp. gallons/day

= 0.7 mgd

And since 1 mgd = 700 gpm

then 0.7 mgd = 700 x 0.7

= 490 Imp. gpm

We can now determine the detention period by dividing the flow into the volume of the tank.

$$\text{Detention Period} = \frac{24{,}960 \text{ Imp. gallons}}{490 \text{ Imp. gallons per minute}}$$

$$= 50.9 \text{ minutes}$$

However, we were asked to determine the detention time in hours

$$\text{Time} = \frac{50.9 \text{ minutes}}{60}$$

$$= 0.85 \text{ hours}$$

Answer - 0.85

Problem 13

In backwashing filters the rate of backwash is important.

(a) If a filter is 15' x 15', what size of pump (U.S. gallons per minute) is required if the rate of backwash is 28 inches per minute?

(b) What is the backwash rate in U.S. gallons per minute per square foot?

Solution

The rate of 28 inches per minute refers to the rise of the water in the filters when the backwash pump is operating.

(a) The pump must be large enough to pump water at a rate of 28 inches per minute over the whole filter area.

Filter area = 15' x 15'

= 225 square feet

Thus, the volume of water required in one minute is

$$\text{Volume} = 225 \text{ sq. ft.} \times \frac{28''}{12}$$

= 525 cu. ft.

We must now convert this figure to U.S. gallons.

1 cu. ft. = 7.5 U.S. gallons

Therefore 525 cu. ft. = 7.5 x 525

= 3937.5 U.S. gallons

This is the volume of water that the pump must handle each minute.

Answer - 3937. 5 U.S. gpm

(b) The backwash rate in U.S. gpm per square foot is simply the total rate of the pump divided by the total number of square feet in the filter.

total rate = 3937.5 U.S. gpm

filter area = 225 sq. ft.

Therefore, backwash rate = 3937.5/225

= 17.5 U.S. gpm/sq. ft.

Answer - 17.5 U.S. gpm/sq. ft.

Problem 14.

A pressure gage on a sewage pump discharge reads 10 psi.

(a) What is the discharge head in feet of water?

(b) Given that the formula for horsepower is:

$$HP = \frac{Q(cfs) \times 62.4 \times \text{Discharge Head}}{550 \times E}$$

where E is the efficiency (assume E = 0.50 (50 percent)

Q is the flow rate in cubic feet per second, and Disch. Head is in feet of water.

What horsepower is required if the discharge is 200 Imp. gallons per minute?

Solution

(a) The pressure gage reads 10 psi. From the table we know that:

1 psi = 2.31 feet of water

Therefore, 10 psi = 2.31 x 10

= 23.1 feet of water

Answer - 23.1 feet of water

(b) We are given the formula

$$HP = \frac{Q(cfs) \times 62.4 \times \text{Discharge Head}}{550 \times E}$$

"Q" is the flow rate in cubic feet per second"

"Discharge Head" is in feet of water. It is 23.1 feet of water as we found in part (a).

"E" is the efficiency of the pump. E = 0.50 as given.

We are asked to find what horsepower is required to enable a discharge rate of 200 Imp. gallons per minute. We must first however change our flow rate from Imp. gallons per minute to cubic feet per second in order that we may use the formula.

From the table we know that:

1 cfs = 374 Imp. gpm

Therefore, 200 gpm $= 1 \times \frac{200}{374}$

$= 0.535$ cfs

Now that we have all the values in the right units, we may substitute the values in the formula to find the horsepower.

$$HP = \frac{0.535 \times 62.4 \times 23.1}{550 \times 0.50}$$

$$= 2.80$$

Answer - 2.80 horsepower

A P P E N D I X   I

FORMULAS AND DATA

TABLE OF UNITS OF MEASUREMENT

LINEAR

1 inch (in.) = 2.54 centimetres (cm.)
1 foot (ft.) = 12 inches = 30.48 cms.

1 metre (m.) = 39.37 inches = 3.28 ft. = 1.094 yd.

AREA

1 square foot (sq. ft. or ft^2) = 144 square feet (sq. in. or $in.^2$)
1 acre (Ac) = 43560 sq. ft)
1 square mile = 640 Ac.

VOLUME AND CAPACITY

1 cubic inch (cu. in. or $in.^3$)
1 cubic foot (cu. ft. or $ft.^3$) = 1728 cu. in. = 7.5 U.S. gal. or 6.23 Imp. gal.
1 gallon (gal). = 4 quarts (qt.) = 8 pints (pt.)
1 litre (L) = 1000 millilitres (mL.) = 1.057 qt. (U.S.) = 0.88 Imp. qt.
= 3.1416 or $\frac{22}{7}$

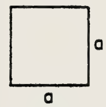
WEIGHT

1 ounce = 28.35 grams
pound (lb. or #) = 16 ounces (oz.) 453 grams (gm) = 7000 grans (gr.)
1 cubic foot of water weighs approximately 62.4 pounds
1 U.S. gallon of water weighs approximately 8.33 pounds
1 Imp. gallon of water weight approximately 10.0 pounds
1 litre of water weighs approximately 1 kilogram or 1000 grams
1 millilitre of water weighs approximately 1 gram
1 foot of water = 0.43 pounds per square inch
1 pound per square inch = 2.35 feet of water

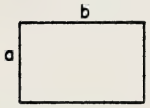
CONCENTRATION

1 part per million (ppm)	= 1 milligram per litre (mg/L)
	= 0.058 grains per U.S. gallon (gpg)
	= 0.07 grains per Imp. gallon (gpig)
1 grain per Imp. gallon	= 14.25 ppm
1 grain per U.S. gallon	= 17.1 ppm
	= 143 pounds per million gallons (lb/MG)

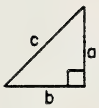
AREAS AND VOLUMES



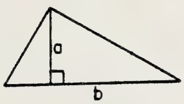
Square -
Area = a x a = a^2



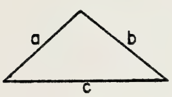
Rectangle -
Area = a x b



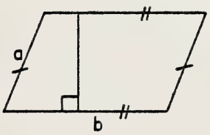
Triangles -
Area = 1/2 b x a $\quad c = \sqrt{a^2 + b^2}$



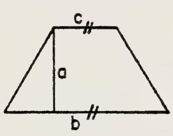
Area = 1/2 b x a



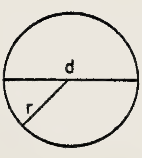
Area = S(S-a) (S-b) (S-c)
Where S = 1/2 (a + b + c)



Parallelogram -
Area = a x b



Trapezoid -
Area = 1/2 (b + c) a



Circle -
Area = πr^2 or $\frac{\pi d^2}{4}$

Circumference = $\pi d = 2\pi r$

Sphere -
Area = $4\pi r^2$ or πd^2
Volume = $\frac{4\pi r^3}{3}$ or $\frac{\pi d^3}{6}$

Cylinder -

Lateral area = $2\pi rL$

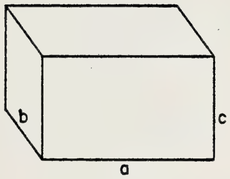
Volume = $\pi r^2 L$

Cone -

Volume = $1/3\pi r^2 L$

Pyramid -

Volume = 1/3 (area of base) x altitude =



Solids -

Volumes of cube or rectangle basin

V = a x b x c

Volume = length x width x height (or depth)

DATA ON CHEMICALS

1) ACTIVATED CARBON - C

(a) Common or trade name: Carbon
(b) Shipping containers: Bags or bulk
(c) Suitable materials for handling:
1) Dry: Iron, Steel
2) Wet: Rubber, silicon, iron stainless steel
(d) Available forms: Black granules, black powder
(e) Weight: 15 pounds per cubic foot
(f) Solubility: (Insoluble)
(g) Commercial strength: From bone - 10%
From wood - 90%
(h) Precautions: Dusty, Dirty, Fire Hazard

2) ALUMINUM SULPHATE - $Al_2(SO_4)_3 \cdot 14H_2O$

(a) Common or trade name: Alum, Filter Alum, Papermaker's Alum Sulphate or Alumina
(b) Shipping containers: Bags, Barrels, Bulk, Cake
(c) Suitable materials for handling:
1) Dry: Iron, Steel
2) Wet: Lead, rubber, silicon, iron, duriron
(d) Available forms: Powder, granules, lump
(e) Weight: 38 - 45 lbs. per cubic foot
60 - 63 lbs. per cubic foot
62 - 67 lbs. per cubic foot
(f) Solubility: 7.2 lbs. per Imperial gallon (32°F)
8.75 lbs. per Imperial gallon (68°F)
(g) Commercial strength: 15 - 22% Al_2O_3
(h) Precautions: Dust Astringent, Irritates eyes, nose, lungs, skin
(i) Characteristics: Store in dry area, tends to cake under high humidity, acidic; mildy corrosive when wet.

3) CALCIUM HYDROXIDE - $Ca(OH)_2$

(a) Common or trade name: Hydrated Lime, Slaked Lime
(b) Shipping containers: Bags, Barrels, Bulk
(c) Suitable materials for handling: Asphalt, Cement, Iron, Rubber, Steel
(d) Available forms: White powder
(e) Weight: 26 - 48 lbs. per cubic foot
(f) Solubility: 1.0144 lbs. per Imperial gallon (90°F)

(g) <u>Commercial strength</u>: 85 - 99% Ca(OH)
(h) <u>Precautions</u>: Irritates eyes, nose, lungs, skin, Mildly corrosive if wet, Store in cool, dry area.

4) <u>CALCIUM HYPOCHLORITE</u> - $Ca(OCl)_2 \cdot 4H_2O$

(a) <u>Shipping containers</u>: 5 pound cans
100, 300, 800 pound drums
(b) <u>Suitable materials for handling</u>: Glass, Rubber, Plastics, Stoneware
(c) <u>Available forms</u>: White Granules, White Powder
(d) <u>Weight</u>: 52.5 lbs. per cubic feet
(e) <u>Solubility</u>: 2.18 lbs. per Imperial gallon (32^oF)
2.29 lbs. per Imperial gallon (68^oF)
(f) <u>Commercial Strength</u>: 70% available Cl_2
(g) <u>Precautions</u>: Gives off Cl_2 on standing in air; irritates eyes, nose, lungs, skin; maximum air concentration = 1 ppm; dust very harmful
(h) <u>Characteristics</u>: Explosive above 100^oC; tends to lump; toxic; highly corrosive if wet

5) <u>CALCIUM OXIDE</u> - CaO

(a) <u>Common or trade name</u>: Burnt Lime; Quick Lime; Unslaked Lime
(b) <u>Shipping containers</u>: Bags, Barrels, Bulk
(c) <u>Suitable materials for handling</u>: Asphalt, Cement, Iron, Rubber Steel
(d) <u>Available forms</u>: Lumps, Pebbles, Granules
(e) <u>Weight</u>: 56 - 67 lbs. per cubic foot
60 - 67 lbs. per cubic foot
50 - 70 lbs. per cubic foot
(f) <u>Solubility</u>: Reacts with water to form $Ca(OH)_2$
(g) <u>Commercial Stength</u>: 90 - 96% CaO
(h) <u>Precautions</u>: Irritates eyes, nose, lungs, skin; reacts with water; burns skin; unstable; mildly corrosive if wet
(i) <u>Characteristics</u>: Hygroscopic; store in cool, dry area

6) <u>CHLORINE</u> - Cl_2

(a) <u>Common or trade name</u>: Chlorine gas; liquid chlorine
(b) <u>Shipping containers</u>: Cylinders, Tank cars
(c) <u>Suitable materials for handling</u>;
1) Dry: Black Iron, Copper, Steel
2) Wet: Glass, Hard Rubber, Steel
(d) <u>Available forms</u>: Liquid (Gas under pressure)
(e) <u>Weight</u>: 91.7 pounds per cubic foot
(f) <u>Solubility</u>: 0.07 lbs. per Imperial gallon (60^oF)
(g) <u>Commercial Strength</u>: 99.8% Cl_2
(h) <u>Precautions</u>: Toxic in air at 1 ppm, irritates eyes, nose, lungs, skin; extremely corrosive if wet

(i) Characteristics: Yellowish gas, forms white vapor with ammonia

7) COPPER SULPHATE - $CuSO_4\ 5H_2O$

(a) Common or trade name: Blue Vitriol, Blue Stone
(b) Shipping containers: Bags, Barrels, Drums
!9 (c) Suitable material for handling: Asphalt, Silicon, Iron, Stainless Steel
(d) Available forms: Crystals, Lumps, Powder
(e) Weight: 75 - 90 lbs. per cubic foot
78 - 80 lbs. per cubic foot
60 - 64 lbs. per cubic foot
(f) Solubility: 1.6 lbs. per Imperial gallon ($32^{o}F$)
2.2 lbs. per Imperial gallon ($68^{o}F$)
2.6 lbs. per Imperial gallon ($86^{o}F$)
(g) Commercial strength: 99% $CuSO_4$
(h) Precaution: Poisonous, dust harmful; mildly corrosive if wet
(i) Characteristics: Hygroscopic; solution acidic

8) FLUOSILICIC ACID - $H_2\ SiF_6$

(a) Common or trade name: Fluosilic Acid
(b) Shipping containers: Rubber lined drums
(c) Suitable materials for handling: Rubber lined drums
(d) Available forms: liquid
(e) Solubility: 1.44 lbs. per Imperial gallons ($68^{o}F$)
(f) Weight: 81 - 83 lbs. per cubic foot
(g) Commercial strength: Approximately 35%
(h) Precautions: Very corrosive; harmful to eyes, skin

9) SODIUM FLUORIDE - NaF

(a) Shipping containers: Bags, Barrels
(b) Suitable materials for handling: Iron, Steel lead
(c) Available form: Powder
(d) Weight: 50 - 75 lbs. per cubic foot
(e) Solubility: 4.05 lbs. per Imperial gallons
(f) Commercial Strength: 90 - 95% NaF
(g) Precautions: Dust; vapors; harmful; toxic
(h) Characteristics: pH of 4% solution 6.6, tends to lump

10) SODIUM CARBONATE - $Na_2\ CO_3$

(a) Common or trade name: Soda Ash
(b) Shipping containers: Bags, Barrels, Bulk
(c) Suitable materials for handling: Iron, Rubber, Steel
(d) Available forms: Light or Dense Powder
(e) Weight: 35 lbs. per cubic foot
65 lbs. per cubic foot
(f) Solubility: 2.76 lbs. per Imperial gallon ($86^{o}F$)
(g) Commercial Strength: 99.4% Na_2CO_3; 58% NaO

(h) Precautions: Dusty; irritates eyes, nose, lungs, skin; store in cool, dry area
(i) Characteristics: Tends to lump; mildly corrosive if wet

11) SODIUM HYPOCHLORITE - $NaOCl$

(a) Common or trade name: Bleach, Chlorine bleach
(b) Shipping containers: Carboys, Drums, Bulk
(c) Suitable materials for handling: Rubber, Plastics, Glass, Ceramics
(d) Available forms: "Solution"
(e) Solubility: Complete
(f) Commercial strength: 5 - 15% available Cl_2
(g) Precautions: Irritates eyes, skin; protect from light; store in cool place
(h) Characteristics: Corrosive; yellowish liquid, strongly alkaline; strong oxidant

12) SODIUM SILICO FLUORIDE - Na_2SiF_6

(a) Shipping containers: Bags, Drum
(b) Suitable materials for handling:
    1) Dry: Steel, iron
    2) Wet: Stainless steel, rubber, plastic
(c) Available forms: fine powder
(d) Solubility: 0.762 lbs. per Imperial gallon (70°F)
(e) Commercial Strength: 98.5% Na_2SiF_6
    60% Fluoride
(f) Precautions: Dust; toxic; mildly corrosive if wet
(g) Characteristics: Hygroscopic; Tends to lump; solution acidic

13) SODIUM HEXAMETA PHOSPHATE - $(NaPO_3)_6$

(a) Common or trade name: Calgon; Glassy Phosphate; Vitreos Phosphate
(b) Shipping containers: 100 lb. bags
(c) Suitable materials for handling: Hard Rubber, plastics, stainless steel
(d) Available form: Crystals, Flakes, Powder
(e) Weight: 47 lb. per cubic foot
(f) Solubility: 1 - 5 lbs. per Imperial gallon
(g) Commercial strength: 66% P_2O5
(h) Characteristics: pH of 0.25% sollution 6.0 - 8.3

CHEMICAL TABLES

BASIC ELEMENTS AND RADICALS ENCOUNTERED IN WATER PURIFICATION

NAME	SYMBOL	NAME	SYMBOL
ELEMENTS		ELEMENTS cont'd	
Alumiunum	Al	Potassium	K
Calcium	Ca	Sodium	Na
Carbon	C	Sulfur	S
Chlorine	Cl		
Copper	Cu	RADICALS	
Fluorine	F	Hydroxyl	OH
Hydrogen	H	Nitrite	NO_2
Iodine	I	Nitrate	NO_3
Iron	Fe	Sulfate	SO_4
Magnesium	Mg	Carbonate	CO_3
Mangenese	Mn	Biocarbonate	HCO_3
Nitrogen	N	Phosphate	PO_4
Oxygen	O	Silicate	SiO_3

COMMON CHEMICALS USED IN WATER PURIFICATION

COMMON NAME	CHEMICAL NAME	FORMULA
Ammonia Gas	Ammonia	NH_3
Ammonia	Ammonium hydroxide	NH_4uOH
Filter Alum	Aluminum sulfate	$Al_2(SO_4)_3 \cdot 18H_2O$
Limestone	Calcium carbonate	$CaCO_3$
	Calcium bicarbonate	$Ca(HCO_3)_2$
Hydrated Lime	Calcium hydroxide	$Ca(OH)_2$
Quick Line	Calcium oxide	CaO
	Chlorine	Cl
	Chlorine dioxide	ClO_2
Bluestone	Copper sulfate	$CuSO_4 \cdot 5H_2O$
	Ferric chloride	$FeCl_3 6H_2O$
Muriatic Acid	Hydrochloric acid	HCl
	Sulfuric acid	H_2SO_4
Salt	Sodium chloride	NaCl
Soda Ash	Sodium carbonate	Na_2CO_3
Soda	Sodium bicarbonate	$NaHCO_3$
Lye	Sodium hyroxide	NaOH
	Sodium phosphate	$Na_3PO_4\ 12H_2O$
Water		H_2O
	Hypochlorous acid	HOCL
Chlorine of Lime	Calcium oxychloride	$CaOCl_2$
	Aluminum hydroxide	$Al(OH)_3$
Gypsum	Calcium sulfate	$CaSO_4$
	Carbon Dioxide	CO_2
	Carbonic acid	H_2CO_3

Bleach	Monochloramine Dichloramine Nitrogen trichloride Methane Calcium hypochlorite Sodium hypochlorite	NH_2Cl $NHCl_2$ NCl_3 CH_4 $Ca(OCl)_2$ $NaOCl$